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LIMNOLOGY OF SOUNDING CREEK, AN ASTATIC, PRAIRIE STREAM

by

JOHN T. RETALLACK ©

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Limnology of Sounding Creek, an Astatic, Prairie Stream," submitted by John T. Retallack in partial fulfilment of the requirements for the degree of Master of Science in Zoology.

ABSTRACT

Sounding Creek, a prairie, endorheic stream in the Consort area of east-central Alberta, was studied from June 1971 until October 1973. Although the stream is of little commercial value apart from marginal irrigation uses and cattle operations, it is the major aquatic basin in east-central Alberta. Succession in the biological populations from a variety of habitats (including both permanent and temporary habitats) was related to corresponding chemical and physical changes. The amount of water in the stream varied widely during the study and, although gross seasonal trends could be easily detected, short periods of heavy rains, resulting in periodic flooding, considerably modified seasonal trends.

Concentrations of chemical constituents varied widely as well. For example, sulphate concentrations in 1973 increased from about 350 mg/l in spring to 2180 mg/l in winter. Total dissolved solids values ranged from about 600 mg/l to 1500 mg/l. The effects of floods on the chemical constituents (sulphates, T.D.S., chlorides, etc.) were quite pronounced, most stations having greatly diluted chemical concentrations at these times.

Three main types of animals were recognized in Sounding Creek: (1) obligate inhabitants requiring astatic conditions (e.g., *Eubranchipus* spp., *Lynceus* spp., etc.); (2) facultative inhabitants existing in both astatic and permanent conditions (e.g., Cladocera, Culicidae, etc.); and (3) permanent water inhabitants (e.g., *Pimephales* and *Culaea*) requiring permanent water conditions for completion of their life cycles.

It was found that changes in plant heterogeneity seemed to be a major controlling factor in the determination of community structure. Life cycles of the typical temporary water inhabitants (e.g., Anostraca and Conchostraca) are included. Some species of each group completed their life cycles more rapidly than others of the same genus and these rapidly growing representatives were determined to be more adapted to temporary conditions. For example, *Lynceus mucronatus* completed its life cycle (hatching-sexual maturity-death) in about 60 days while *L. brachyurus* required as many as 120 days to complete its cycle. Only one anostracan species, *Eubranchipus ornatus*, exhibited a rapid life cycle and was only present for about one month. The other species, *E. bundyi* and *E. intricatus*, required considerably more time to complete their life cycles (about 2 to 2.5 months). Descriptions of the nauplii of *L. mucronatus* and *L. brachyurus* are included.

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INTRODUCTION

Several studies have been done on inland, saline and temporary bodies of standing water. Mozley (1932), Rawson and Moore (1944), Kenk (1949), and Moore (1952) have made important contributions to this subject. One of the few accounts of the limnology of temporary saline streams is that of Jewell (1927). A few other articles dealing with prairie streams (Pionke and Nicks, 1970; Pionke, Nicks and Schoof, 1972; and Pionke and Workman, 1972) give only physically or chemically related information.

Temporary waters often occur in basins with no surface outflow. These basins are termed endorheic. Martonne (in Hartland-Rowe, 1966), distinguished between two kinds of endorheism. Arheic basins have neither precipitation nor surface run-off. Euendorheic basins are characterized by locally originating water either flowing into a closed basin or evaporating.

Decksbach (in Remane and Schlieper, 1971) divides astatic (temporary) standing waters into two groups: seasonally astatic waters, which dry up annually, and perennially astatic waters displaying marked yearly fluctuatuons but not necessarily drying up annually. Spandl (in Remane and Schlieper, 1971) restricts the term "temporary" to bodies of water existing for no more than one and one-half to two months. My study area, therefore, generally falls within Decksbach's perennially astatic category.

Basically, the salinity level of water is controlled by hydrological and geological variables. Important hydrological variables

are the amount of precipitation and evaporation potential; the prime geological variables are composition and concentration of the formation salts. Inland salinity, as defined by Pionke, Nicks and Schoof (1972), is 60% of the electrical conductivity expressed in micromhos. This figure is approximately equal to the total dissolved solids.

Precipitation usually contains small concentrations of dissolved substances, although Loewengart (1961) reports that average rainfall in Israel and Jordan contained more than 2 mg/l chloride. In contrast, ground water originating in areas of high salinities might contain high concentrations of dissolved salts. The only main mechanism of water loss in closed systems is via evaporation. One would therefore expect a trend toward saturation of dissolved salts. But as Hutchinson (1937) suggests, wind action may remove salts during the dry phase of temporary water succession. Wind, however, does not remove all excess salts. In many of the Saskatchewan saline lakes and ponds there is a trend toward increasing salinity, both over long periods of time and within the annual successional cycle (Rawson and Moore, 1944).

Unlike most streams of Canada and the United States, prairie streams are usually almost devoid of bank vegetation. Most temperate streams flow through wooded valleys, receiving shade and dead vegetation from the associated trees. The decomposing allochthonous matter in such streams is important as an energy source and provides food and shelter for a variety of animals. In contrast, prairie streams receive relatively little allochthonous material; although substantial amounts may be contributed by farm animals and migratory birds (Daborn, 1969 and 1974).

Prairie streams containing water for most of the year are usually reduced to a series of pools by late summer and may become completely dry by winter. These streams, such as Sounding Creek, tend to have faunas more similar to faunas of ponds (including temporary ponds) than to faunas of smaller permanent streams (Jewell, 1927). Animals inhabiting temporary waters are subjected to extreme and rapidly fluctuating environmental conditions, such as temperature and salinity.

Because of the shallow depths of most astatic water, there is usually complete mixing of the water column and hence complete mixing of nutrients and sediments. Turbidity of such water might be as high as 1700 JTU (Daborn, unpublished data, May 1972, for a highly turbid pond in east-central Alberta). General mixing has a profound effect on the inhabitants of the pond or stream and this will be discussed later.

In North America, the principal range of temporary, saline bodies of water is confined to the Great Plains area. In Canada, these areas are confined to Saskatchewan, the eastern parts of Alberta and the western parts of Manitoba (with the exception of a few areas such as the arid regions of central British Columbia). Temporary waters are of varying commercial value (irrigation, waterfowl and shorebird production, etc.), and in some areas, such as the farming area of central Alberta, are considered a nuisance and are drained. In the eastern part of the province of Alberta, semi-arid conditions prevail and water is in relatively short supply. Sounding Creek, an astatic stream 24 km east of Consort, Alberta, is an example of a stream in such an area and is the subject of this thesis.

The present study was initiated to inventory the physical, chemical and biological characteristics of a prairie, saline stream. This is one of the few studies pertaining to temporary streams in Canada and, to my knowledge, represents the first detailed study of the limnology of astatic, endorheic streams in Canada. The primary objectives were to study the life histories and temporal sequence of species (particularly the Crustacea) inhabiting the stream and other closely associated water bodies and relate the biotic changes to the physical and chemical conditions. Field collections were started in the summer of 1971, but detailed sampling was not implemented until April 1972. The stream was sampled through September 1973.

DESCRIPTION OF STUDY AREA

HISTORICAL

Sounding Creek is important in the history of eastern Alberta. Known in Blackfoot as "oghta-kway" and in Cree as "ni-pi-kap-hit-i-kwek" (Sounding Water), the name Sounding Creek originated in an old Indian legend. The legend is about an eagle with a snake in its claws that flew out of Sounding Lake making a rumbling noise like thunder . . .[1] thus sound water and later Sounding Lake and Sounding Creek.

The site of the signing of treaty number 7 with the Blackfoot and Plains Cree is located on the south end of Sounding Lake. At this signing Big Bear, then chief of the Plains Cree, became disenchanted with the arrangements being made and a battle nearly developed. Instead, he and his warriors fled south into the United States, avoiding a major confrontation.

The North West Mounted Police had a barracks in the Neutral Hills just west of my study area in the 1890's. The sole purpose of this post was to intercept horse thieves who used the area south of Sounding Lake as a resting stop on their way to the United States.

GENERAL AREA

Drainage from the Province of Alberta is in two main directions. The North and South Saskatchewan Rivers drain east into Hudson's Bay;

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[1]Holmgren, E. J. and P. M. Holmgren, 1972. 2000 place names in Alberta. Modern Press, Saskatoon. 226 pp.

the rivers of northern Alberta drain north into the Arctic Ocean. A small section of southern Alberta contributes to the Mississippi system. In the east-central part of the province is a large non-contributing basin, the Sounding Creek Basin (Figure 1). Although within the Hudson's Bay drainage basin area, I suggest that the Sounding Creek Basin, in fact not contributing to northern drainage, is large enough to be considered separately.

Sounding Creek runs for about 200 km, beginning near Sullivan Lake (52° N and 112° W), and flowing into Sounding Lake (52° N, 111° W). Eyehill Creek leaves Sounding Lake and travels 90 km before flowing into Manito Lake, Saskatchewan. Rawson and Moore (1944), in their extensive survey of Saskatchewan's saline lakes, found Manito Lake to be quite saline (20,268 mg/l). Monitor Creek empties into Sounding Creek near my study area after travelling 55 km from its source. Two lakes, Sounding Lake and Grassy Island Lake, are the only major bodies of water along the stream course and both have dried up at least once in the past 50 years. The total drainage area of the Sounding Creek endorheic basin is approximately 14,500 km^2 (5,600 mi^2), an area equivalent to the size of Northern Ireland or 2.25% of the area of Alberta.

The average gradient of the main channel is about 0.71 m/km (Figure 2). For most of the year, there is very little discharge or no discharge at all. However, after the snow melts in spring and during floods, the stream might contain a large amount of water, e.g., up to 14.89 m^3/s in June, 1973.

For most of its length, the stream meanders through a prairie-parkland transition zone over flat ground. Numerous deposits of

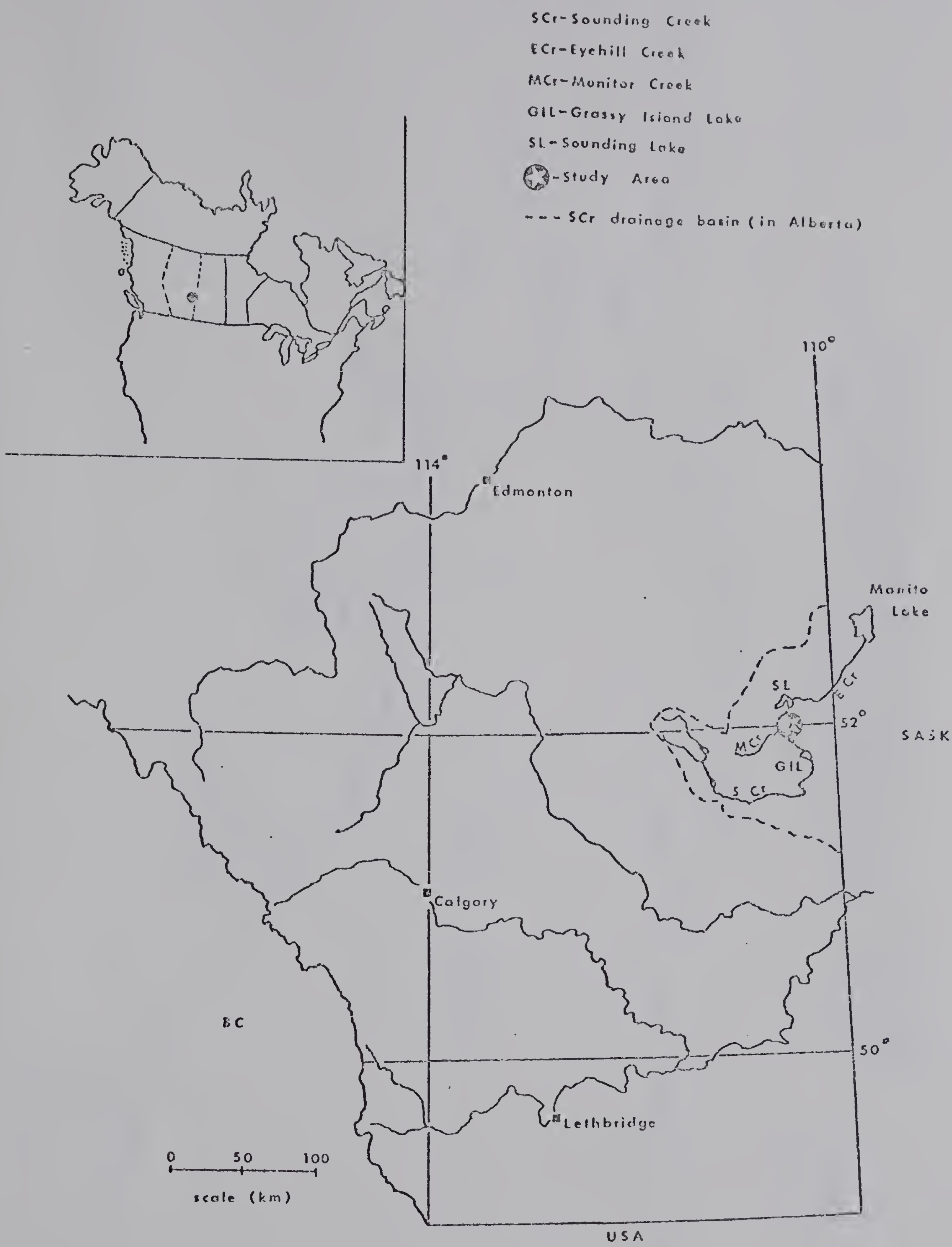

Figure 1. Location of the Sounding Creek drainage basin in Alberta. Inset map shows the position of the study area in North America (dark dot is approximate position of the study area).

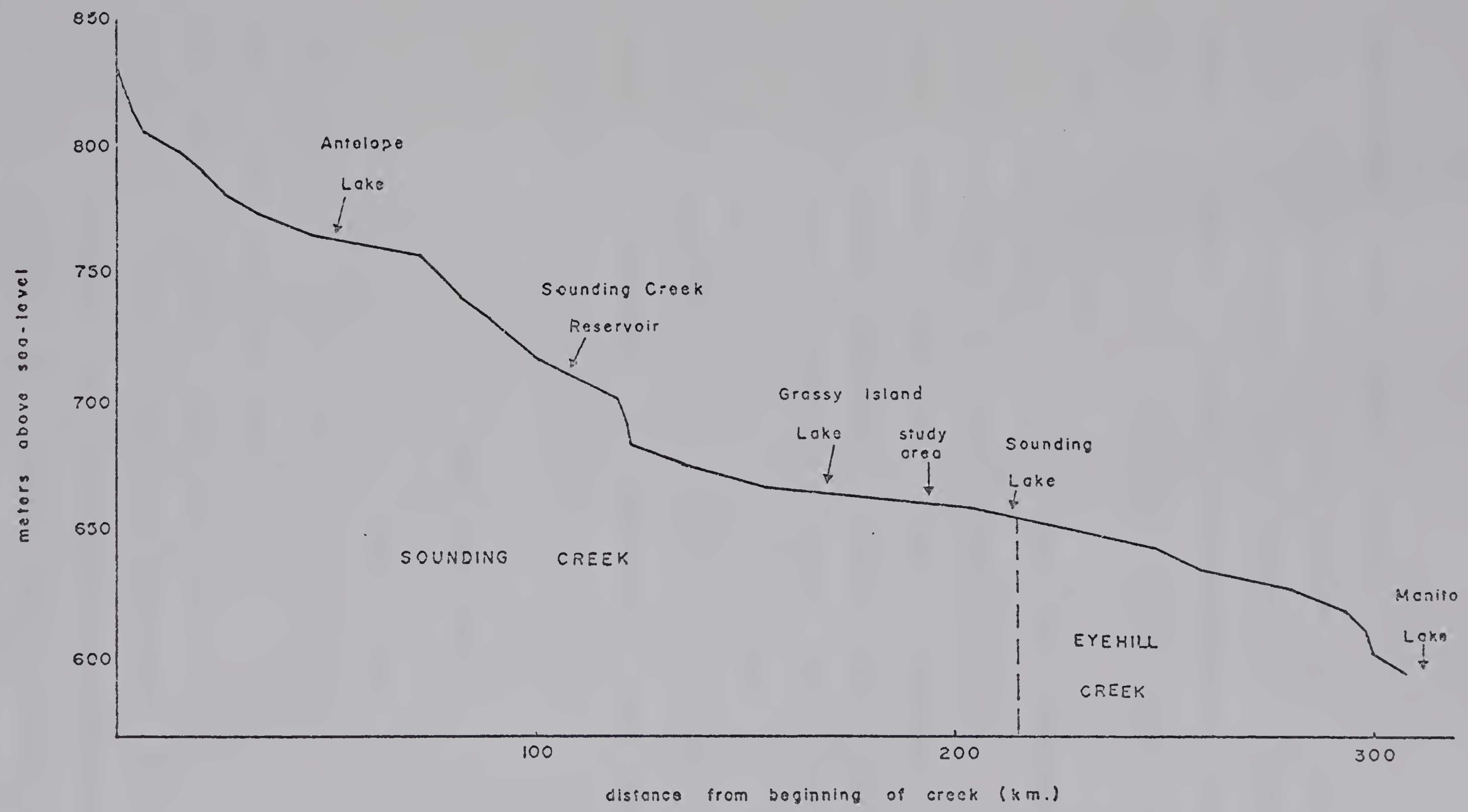

Figure 2. Profile of the Sounding Creek and Eyehill Creek main channels. Data are taken from 25-foot contour interval maps (7.62 m). The broken line separates the two sub-basins.

predominantly sulfate salts are found in the stream's watershed (plate 1). These deposits are the result of upwelling of sulfate-enriched groundwater. Underlying the east-central part of Alberta are extensive Cretaceous deposits of the Belly River and Bearpaw formation, the Belly River formation being of freshwater origin. These deposits are covered by glacial drift material.

Koeppen (cited by Longley 1972) lists the Sounding Creek area as being moist steppe, i.e., areas where plant growth is hindered by lack of soil moisture. Rowe (1972) included the Sounding Creek Basin in his grassland category, the study area proper being located in the northernmost extension of the short-grass prairie. Mean annual precipitation is only 33 cm, and of this 9 cm is snowfall. From 1920 to 1950, mean potential evapotranspiration was about 56 cm, leaving a 23 cm moisture deficit. The mean annual air temperature is about +2 C, with a temperature range of about -40 C to +32 C.

STUDY AREA PROPER

The study area is located between Grassy Island Lake and Sounding Lake (Figure 3). In this area, the stream occupies a deep 3.2 km wide valley, the sides being about 75 m (250 ft) above base level (plate 2). The valley is almost devoid of trees except for a few willows (*Salix*) clumped near the stream edges and around oxbows. Terrestrial vegetation includes prairie cone-flower (*Ratibida columnifera*), thistle (*Cirsium* sp.), sage (*Artemesia* sp.), common bluebell (*Campanula rotundifola*), prairie crocus (*Anemone patens*) and prickly bear cactus (*Opuntia polyacantha*). The stream is bounded by *Eleocharis*. Large clumps of

Plate 1. Encrusting sulphate salts in the drainage basin, west of station F, 13 June 1973

Plate 1

Figure 3. Map of the Sounding Creek study area, including the seven sampling sites (Arabic numerals and station F)

xxx sites of beaver dams

--▷ direction of stream flow

---- shoreline of the stream on mapping date (11 August 1973)

... fence lines

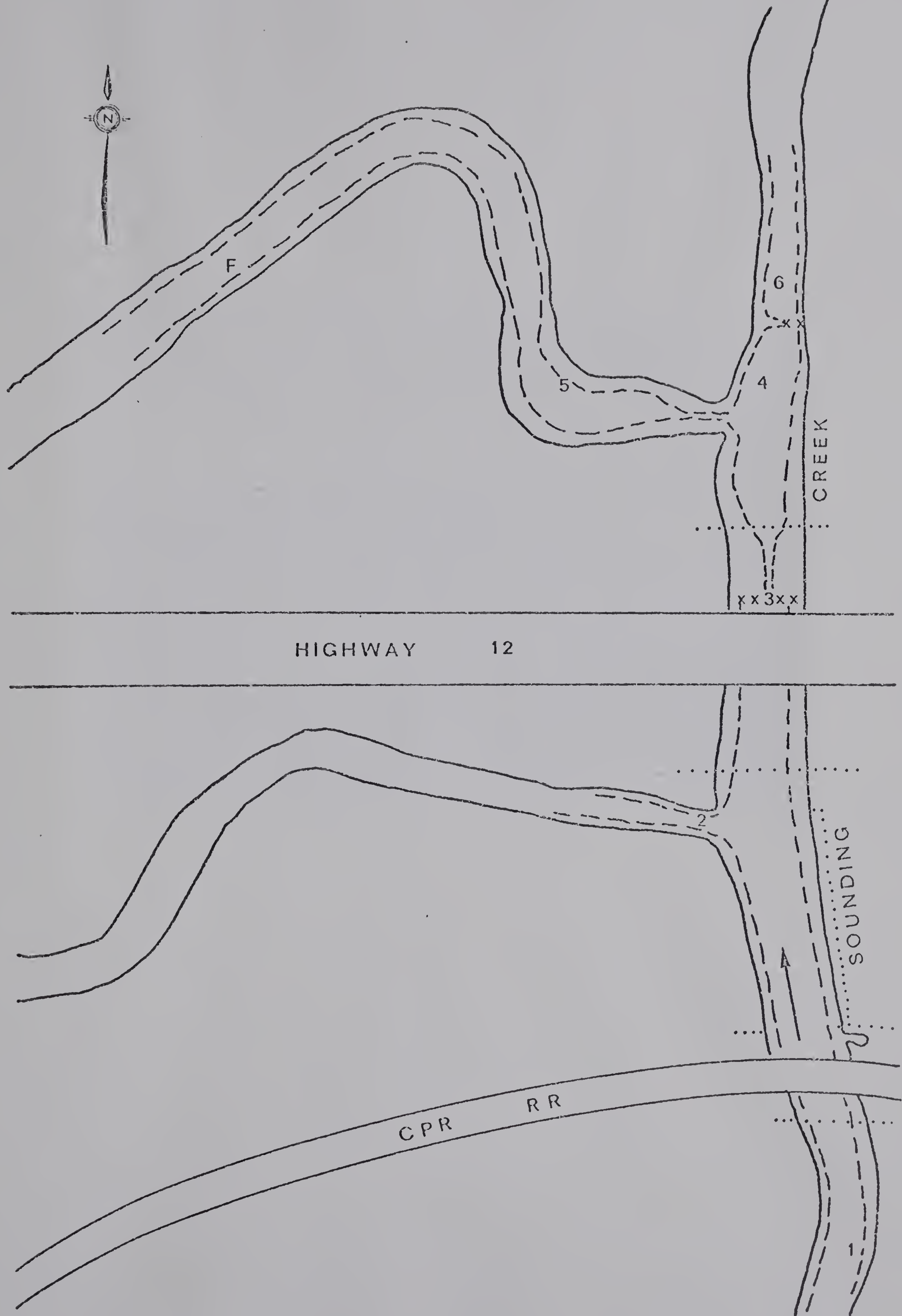
N
F
6
5
4
CREEK
3
HIGHWAY 12
2
SOUNDING
CPR RR
1

Plate 2. View of meandering section of Sounding Creek, 2 km north of the study area (25 April 1973); the viewer is looking southwest. The stream is about 5 km to the southeast while the hills are about 15 km away.

Plate 2

Carex spp. and smaller, rarer clumps of *Scirpus* are found scattered along the stream banks; they extend slightly farther into the water than does the *Eleocharis*. Within the water, *Sium suave*, *Sagittaria lattifolia* and *Lemna trisulca* are dominant in the more temporary stations (stations 5 and F), but only occasionally found in the mainstream ones.

The alkali areas are composed of white alkali (plate 1) which is made up mostly of sodium, magnesium, sulphate and chloride. It is not considered toxic to plant growth which is hindered only if the alkali is in a concentration greater than 0.5%. In contrast to black alkali (sodium carbonate and bicarbonate rich) the main salts of white alkali are neutral in action and not highly alkaline. The area around Monitor Creek has sodium-based salts in concentrations as great as 2% of the total soil volume but the Sounding Creek bed has salt concentrations of less than 1%.

By standard soil classification, the study area proper and the glacial outwash valley near my study area fall within the 1.5.5. division (Wyatt and Nelson, 1938), that is:

1. brown soil, typical of the bald prairie of southeast Alberta, low in nitrogen, develop under low annual rainfall;
5. alluvial origin, sands and gravel prevalent;
5. slightly saline, poor drainage and, therefore, much surface flow or stagnation--salts move up or down the horizon depending on evaporation and penetration of water.

The study area encompassed about 300 m of stream channel, the channel in this area being relatively straight when compared to the meandering channel for much of the stream's length. The straight channel was probably brought about during construction of two bridges over the

stream. Until the bridges were built, this area also exhibited a large meander (plate 3).

There are two beaver dams within the study area, and the beavers proved to be a nuisance as will be described later. One dam is located a few meters north of the Highway 12 bridge; the other is located about 50 m farther north. Cattle have access to the stream at most stations and account for a fairly high annual stream organic input.

INDIVIDUAL STATIONS

Relative positions of the different stations and substrate types are summarized in Table 1 (see also Figure 3).

Station 1. This station exhibits the deepest water, at certain times being about 2 m deep. The substrate is very loose and appears as fine black mud (fairly high in hydrogen sulphide) covering a clay base. There are several small willows on the east bank of the station, and hence there is an unusually large amount of decomposing leafy material in the bottom mud.

Station 2. This station is similar to station 1, but the depth is only about 1.5 m, and there are fewer willows on the banks and consequently less visible organic material.

Station 3. This is the so-called fast-water area. This is the only station where there is a detectable current, and then only at certain times. During most of 1973, flowing water could be observed at

Plate 3. Aerial photo composite of the Sounding Creek valley and the study area (one cm = 0.5 km). The large circle delineates the study area.

1. borrow pit (gravel pit) to the west

2. Monitor Creek

3. Sounding Creek

4. overflow pond to the south

Plate 3

Table 1. Location of the stations and their substrate types

Station	Distance and direction from highway bridge	Substrate type
1	160 m south	mud bottom
2	40 m south	mud bottom
3	5 m south	hard-packed clay
4	65 m north	mud-sand and gravel
6	95 m north	mud bottom
	Distance and direction from confluence with mainstream	Substrate type
5	50 m west	mud bottom
F	145 m west	mud bottom

this station. The substrate is composed of hard clay.

Station 4. The substrate of this station is a mixture of soft black ooze, hard-packed clay and mud-gravel. The water is fairly shallow, rarely exceeding 1 m in depth, except during floods.

Station 6. This station is located only a few meters downstream from station 4. Station 6 is characterized by very loose, black ooze containing hydrogen sulphide. Except during floods and the spring breakup, the water is only about 0.5 m deep and contains a lot of organic material. This is the only station with *Carex* extending across the entire width of the channel.

Station 5. This station is not part of the main channel and can best be described as a pond. It is fed from runoff from the F area. The banks slope gradually and are covered with emergent macrophytes. Depth varies from 0 to 1.5 m; the bottom is composed of black mud.

Station F. Because of its relation to station 5, this station was designated the "Feeder" Creek. It is part of an old meander now cut off by the highway. The station is shallow, rarely exceeding 0.5 m except in the numerous cow-print potholes, where the water might be from 0.5 to 1.0 m deep. The channel is choked with *Sium* and *Sagittaria*, and the substrate is of loose black mud including much partially decomposed vegetation.

MATERIALS AND METHODS

PHYSICAL

Work on Sounding Creek during the period from June to October 1971 was exploratory. Stations were located, physical and chemical parameters to be measured were decided upon, and an effort was made to discover the types and distribution of aquatic biota.

Water temperatures were taken in conjunction with oxygen determinations by submerging a pocket thermometer to a depth of about 10 cm.

When possible, flow data were obtained from field observations, but because of the very low discharge rates for most of the summer, this was possible only infrequently. Most discharge data were obtained from the Department of the Environment, Inland Waters Branch, Water Survey of Canada. The nearest Sounding Creek gauging station is 50 km south of the study area (25 km north of Oyen, Alberta). Since Monitor Creek plays an important role in determining the total stream discharge, discharge measurements were also taken for Monitor Creek at a site 1.5 km south of the town of Monitor and 5 km west of the study area.

Relative water levels were measured by utilizing a railway piling marked with a sheet metal strip. It was found later that different stations had widely varying rates of water loss due to evaporation or surface flow. Therefore in 1973, stakes were set out at individual stations.

Precipitation and air temperature data for 1972 and 1973 were obtained from Coronation, Alberta (70 km west of the study area), and Macklin, Saskatchewan (45 km northeast of the study area). All atmospheric data were obtained from Environment Canada, Atmospheric Services. Evapotranspiration, mean temperatures, mean precipitation, mean runoff and mean moisture deficit data were taken from either Longley (1972) or Neill *et al.* (1970).

CHEMICAL

Samples for chemical analysis were taken at the same site on each sample date. Dissolved oxygen samples were taken from approximately 10 cm below the water's surface. All samples were taken between 11:00 AM and 12:00 noon; they were immediately fixed through the acidification stage of the azide modification of the Winkler method. Samples were stoppered and returned to the laboratory where titrations were completed within 24 hours.

Samples for color, turbidity, and the remaining chemical components were taken in the same way as the oxygen samples but were placed in a tightly closed, one-liter plastic bottle and returned to the laboratory where they were stored overnight at 5 C. Immediately before analysis the samples were warmed to room temperature. Analysis was usually completed within 36 hours of sampling. The American Public Health Association (1960) recommends a 72-hour time lapse as the maximum permissible limit for unpolluted waters. All samples were analyzed by Mrs. G. Hutchinson in the Department of Zoology's water laboratory. The following chemical parameters were determined according to A.P.H.A's

Standard Methods (1971): total dissolved solids, chloride, sulfate, pH, alkalinity (as $CaCO_3$), orthophosphate, conductance, and hardness (as $CaCO_3$).

BIOLOGICAL

Biological samples were obtained from April 1972 to November 1973. Techniques employed throughout the study were similar and will be discussed individually. Table 2 outlines the sampling schedule for the 1972-1973 period.

Plankton Samples

Plankton samples were the only strictly quantitative biological samples that were obtained. Samples were collected by either (a) pouring a measure volume of water (20.9 liters) through a #20 plankton net or (b) taking a vertical haul through a known distance with the same #20 plankton net. The second method was only employed when the water was more than 35 cm in depth. The net's filtering area was 107.45 cm^2. Plankton samples were preserved in the field with 10% formalin and transported to the laboratory. In the laboratory the field samples were homogeneously mixed. Two subsamples, each 1 ml in volume, were withdrawn with an automatic pipette, transferred to a Sedgewick-Rafter counting cell and covered by a cover slip. Counts were made for the entire S-R cell using 100 power magnification. The numbers obtained for the two counts were averaged and converted to numbers of organisms per liter.

Because of the weedy, littoral nature of most of the study area,

Table 2. Summary of the sampling program for the period 1972 to 1973

Date		Water sample or chemical analysis	Plankton sample (quantitative)	Dip-net sample (qualitative)	Ekman or core sample
(1972)					
April	19	X	X	X	X
May	3	X	X	X	X
	25	X	X	X	-
June	16	X	X	X	X
July	7	X	X	X	X
	27	X	X	X	X
August	16	X	X	X	X
October	7	X	X	X	-
	22	General observation only			
December	29	X	-	-	-
(1973)					
March	10	General observation only			
April	4	X	-	-	-
	5	-	-	X	-
	8	-	-	X	-
	10	X	-	-	-
	11	X	-	-	-
	12	-	-	X	-
	25	X	X	X	-
May	2	X	X	X	-
	9	X	X	X	-
	16	X	X	X	-
	22	X	X	X	-
	30	X	X	X	-
June	7	X	X	X	-
	13	X	X	X	-
	20	X	X	X	-
July	5	X	X	X	-
	17	X	X	X	-
August	1	X	X	X	-
	15	X	X	X	-
October	13	X	X	X	-

the samples were not planktonic in the strictest sense and many littoral organisms were collected, e.g., *Scapholeberis kingi* and *Diaphanosoma brachyurum*. An effort was made, however, to avoid as much as possible the weedy areas and other substrate material.

Dip-Net Samples

Qualitative samples were taken with a fine-meshed dip-net having a mean mesh aperture of 134 microns. Marker stakes were set out to delineate the exact area to be sampled. Collecting time was equally split between littoral and open-water sampling. The samples obtained were deposited in wide-mouth plastic jars and preserved with formalin. Laboratory procedure for analyzing these samples consisted of hand-picking as many of the larger animals as possible and then subsampling the remaining material with a custom-made quadrant subsampler. Counts and measurements were made with a Zeiss-Jena dissecting microscope at 50X magnification.

Other Samples

Ekman dredge samples could only be taken from bridges. Samples were taken with a 6-inch (232 cm^2) Ekman dredge and were returned to the laboratory. In the laboratory samples were sieved to remove the fine mud and then the organisms were counted and identified. Sampling with a coring device was tried in mid-1972, but this proved unsatisfactory and was discontinued.

Floating box-type emergence traps were also set out for the duration of the study, but due to extremely variable water conditions and considerable vandalism, the traps were not very successful.

Identification of Organisms

Several important taxa were not considered in this study. These included bacteria, fungi, protozoans, diatoms and most phytoplankton. Several taxonomic references were used for identification: Ahlstrom (1940), Ahlstrom (1943), Brandlova *et al.* (1972), Brooks (1957, Brooks and Kelton (1967), Goulden (1968, Hotchkiss (1972), Needham and Westfall (1955), Pennak (1953), Prescott (1970), Smith (1950), Usinger (1956), Walker (1953), Ward and Whipple (1959).

RESULTS

PHYSICAL AND CHEMICAL CHARACTERISTICS

Chemical composition is determined by a number of interrelated factors. Some of the more important chemical factors associated with Sounding Creek are pH, dissolved oxygen, alkalinity, total dissolved solids, sulphates and chlorides. The most apparent and probably the most important physical feature influencing life in Sounding Creek is the seasonally varying amount of water, especially the paucity of water in late summer. Since Sounding Creek is a closed stream basin, evaporation, precipitation and ground water discharge play an important role in determining the instantaneous ionic concentration, which indicates the state of the system only at the moment of sampling. Plates 4 to 7 illustrate seasonal periodicity through one complete wet phase cycle.

Chemical and physical data not covered extensively in the text are included in the Appendices.

Water Temperature

Water temperatures ranged from 0 C under the ice in winter (1972-1973) to 28 C in summer 1973 (Table 3). After the passage of the ice in spring, the stream warmed rapidly and by mid-May had reached summer maximum temperatures. Changes in maximum and minimum temperatures were similar at all stations except station 1, which, because of its greater depth and shading, was slower to react to changes

Plates 4, 5, 6 and 7. Series of photographs, looking north, through a typical wet phase cycle

Plate 4. 29 December 1972

Plate 5. 8 April 1973

Plate 6. 22 May 1973

Plate 7. 22 October 1973

Plate 4

Plate 5

Plate 6

Plate 7

Table 3. Water temperatures in Sounding Creek stations, 1973. Numbers in brackets indicate minimum-maximum temperature values.

Date	Station 1	3	4	5	6	F
04/4	1.5	1.5	2.0	5.5	3.0	5.0
04/6	-	1.0	1.0	1.0	1.0	1.0
04/11	12	8	9	13	9	6
04/25	11	11	12(2-12)	12(2-13)	11(2-11)	12(1-14)
05/2	12	12	11(2-11)	12(2-13)	12(2-12)	12
05/9	12	12	12(7-17)	12(7-17)	13(6-16)	13
05/16	18	17	20(9-23)	17(9-23)	17(9-23)	20
05/22	17	17	17(8-22)	17(8-23)	19(10-24)	19
05/30	19	20	19(12-22)	19(12-22)	19(10-24)	19
06/7	16	16	17(11-23)	16(12-22)	17(10-23)	16
06/13	19	20	21(11-24)	19(12-22)	19(10-22)	20
06/20	16	18	17	19	17	18
07/5	17	-	19(11-28)	16(10-22)	19(11-27)	18
07/17	15	16	16(10-27)	17(10-24)	16(10-27)	18
08/1	20	21	21	22	21(1o-27)	22
08/15	20	20	21	23	22(10-28)	23
10/13	2.5	2.5	2.5	3.0	2.5	3.0

in air temperatures. Because the water is so shallow at most stations and the whole area is exposed to wind, the system is constantly mixed and a thermocline never develops.

Hartland-Rowe (1972) found daily water temperatures in the semi-arid areas of the province changing at a rate as high as 4 C per hour and the overall daily temperature range to be as high as 18 C. The greatest recorded rate of change in Sounding Creek was 4 C per hour on 25 July 1972 when the temperature dropped from 19 C to 15 C as a result of cold rain coupled with a drop in nighttime air temperatures. Usually, however, the daily temperature range in Sounding Creek rarely exceeded 3 or 4 degrees.

Air Temperatures and Precipitation

Precipitation and air temperature data for both Macklin, Saskatchewan, and Coronation, Alberta, are summarized in Table 4 and plotted separately for Coronation in Figure 4. For comparison, precipitation data from Alix and Pemukan, Alberta (about 1.5 km south-east of the study area), are also included (Table 5). There are distinct local variations in weather and distinct year-to-year variations. Alix, located in aspen parkland, is about 177 km west of Pemukan. There was as much as 28 cm difference in precipitation between the two areas in 1932, the mean difference being about 9.4 cm (Table 5). Generally, the area around Pemukan is considerably drier than the area to the west and much more susceptible to evaporation. Table 6 summarizes monthly precipitation data for 1929-1930, the driest year recorded at Pemukan between 1905 and 1937. Coronation is about 70 km west of Sounding Creek at the study area and Macklin is about

Table 4. Mean maximum and minimum ($\bar{X}$) air temperature in Celsius and total monthly precipitation (ppt) in cm at Coronation, Alberta, and Macklin, Saskatchewan, from January, 1972 to November, 1973

Date	Macklin			Coronation		
	ppt	$\bar{X}$ max.	$\bar{X}$ min.	ppt	$\bar{X}$ max.	$\bar{X}$ min.
1972						
J	3.55	-15.6	-24.0	3.48	-14.0	-24.0
F	3.17	-13.9	-20.0	4.26	-13.0	-20.0
M	0.71	-1.7	-11.7	1.42	-1.0	-10.0
A	0.51	10.6	-3.3	0.84	10.0	-8.0
M	0.99	20.0	3.6	2.49	19.0	4.0
J	4.01	23.6	8.9	3.65	22.0	9.0
J	9.42	20.6	8.9	7.77	20.0	9.5
A	2.94	25.3	11.0	6.50	24.5	12.0
S	3.02	-	-	3.88	12.0	1.5
O	0.45	8.3	-4.0	0.53	8.5	-4.0
N	1.44	-0.3	-6.5	1.75	-0.3	-6.6
D	1.16	-12.5	-14.0	1.55	-11.0	-20.0
1973						
J	0.38	-6.4	-17.0	1.09	-6.0	-16.5
F	-	-6.1	-15.6	1.34	-5.5	-15.5
M	1.70	5.0	-7.5	1.80	5.0	-5.0
A	3.10	7.8	-2.8	3.55	8.0	-2.5
M	2.03	19.4	4.5	2.36	18.0	4.0
J	9.27	22.8	8.3	17.06	21.0	9.0
J	6.45	24.4	10.0	6.19	23.0	10.5
A	10.61	23.9	10.3	10.23	22.5	10.0
S	1.67	17.5	4.8	1.45	17.0	4.5
O	1.19	11.7	-0.3	1.93	11.0	-1.0
N	2.64	-8.8	-16.0	2.87	-8.5	-16.4

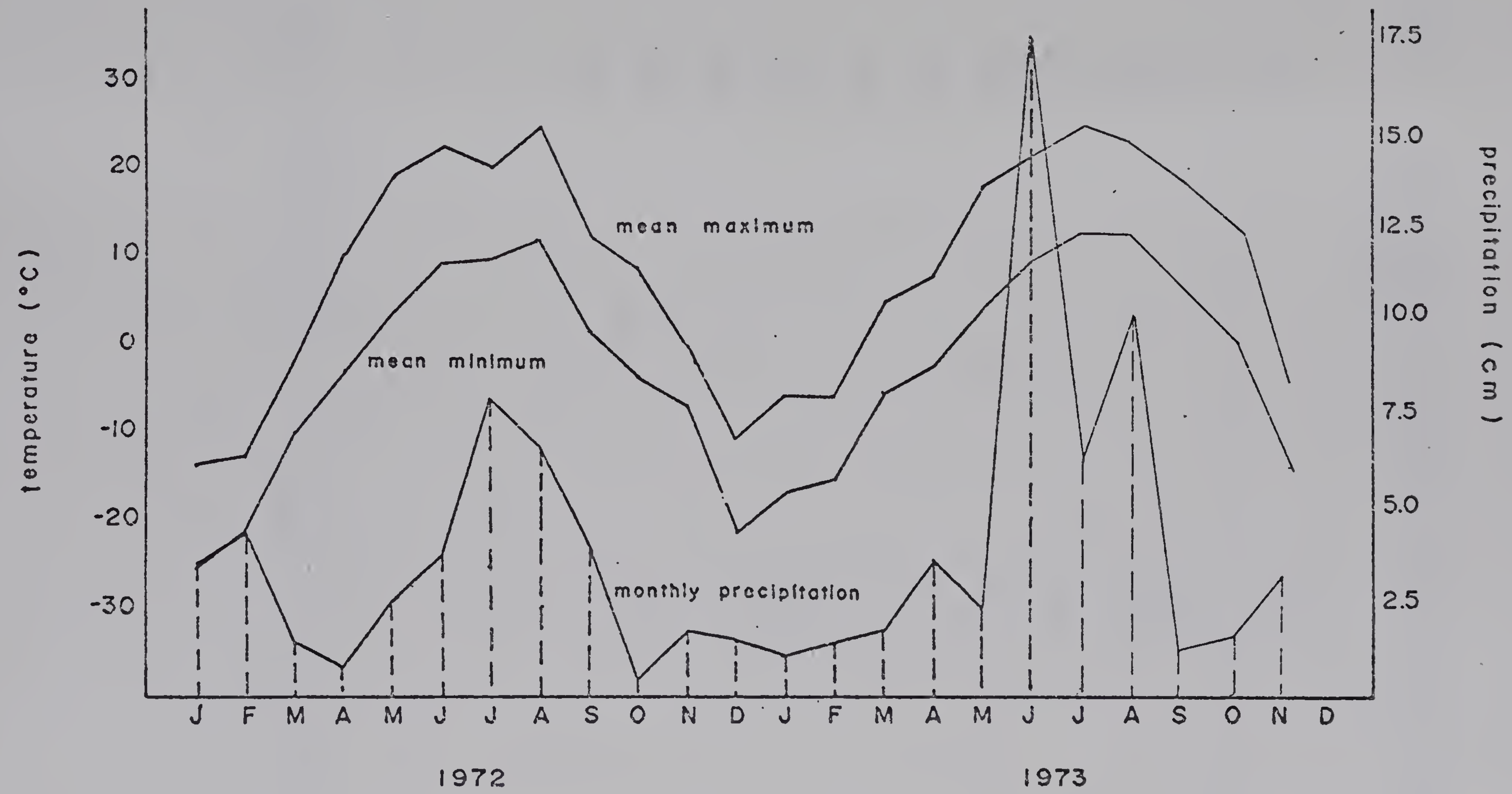

Figure 4. Mean monthly maximum and minimum temperatures and monthly total precipitation values, Coronation, Alberta

Table 5. Total yearly precipitation (cm) for Pemukan and Alix, Alberta, 1927-1936[a]

Date	Alix	Pemukan
1927	54.91	60.25
1928	34.41	40.48
1929	28.47	25.14
1930	31.39	41.70
1931	53.08	24.97
1932	47.42	25.45
1933	51.66	30.12
1934	29.77	22.68
1935	51.41	34.11
1936	43.76	27.53
	$\bar{X}$ 42.62	$\bar{X}$ 33.25

[a]Adapted from a Table in Wyatt, F. A., J. D. Newton, W. E. Bowser and W. Odynsky (1938). Soil Survey of the Sullivan Lake Sheet - 1938. Bulletin #31, University of Alberta, College of Agriculture. 102 p.

Table 6. Monthly precipitation (cm) for 1929/1930, the driest year during the period 1905-1937, at Pemukan, Alberta[a]

Month	1929-1930 Precipitation
August	0.45
September	2.49
October	0.51
November	2.99
December	2.23
January	1.98
February	2.03
March	2.92
April	2.41
May	3.78
June	1.11
July	2.21
TOTAL	25.14

[a]Adapted from a Table in Wyatt *et al.* (see Table 5).

45 km east of my study area. Temperatures differ little between the two stations. In contrast, rainfall varies considerably between the two areas. The results emphasize the need for local meteorological data when work is carried out in semi-arid areas.

Ice Conditions

Exact freeze-up dates during the study period are not known; the stream usually freezes over during the last two weeks of October when the mean air temperature drops below 0 C. In 1973 the ice began to form during the second week of October.

Because the stream dries up at most stations, there are few areas in winter where ice in fact covers free water. Station 1 is an exception. At this station on 29 December 1972 the ice was 33 cm thick, and by the beginning of March the ice had increased in thickness to 100 cm leaving 130 cm of free water beneath; but there was very little snow cover on either sampling date. Stations 3, 4, 5, 6 and F had a thin ice layer below a thin hard packed snow cover but there was not free water below the ice. The only place where there was substantial snow cover was on the leeward side of the stream banks. Generally there was only a thin snow cover for most of the area and patches of bare ground in winter were quite common.

The ice breaks up in the spring at different times at different stations. In 1973 breakup occurred about 1 April at stations 1, 3, 4 and 6, but there were still many pieces of floating ice on 3 April 1973. At this time stations 5 and F were still frozen over with very porous opaque ice. Ice on station 5 melted on 4 April. Surface ice on station F was completely melted by 7 April. On the night of 8 April,

air temperature dropped to -7° C, and a 1.5 cm sheet of ice reformed over the station trapping the invertebrates between the surface ice and the exposed ice frozen to the surface of the substrate (anchor ice). Water temperature between the surface and anchor ice was 0.5 C and many moribund animals were observed on the surface of the anchor ice. This will be discussed further in the biological section. In 1973, anchor ice did not disappear until April 25. Sediment ice did not melt until mid-May.

Discharge

Figure 5 compares discharge data from Monitor Creek and Sounding Creek to precipitation data from Coronation, Alberta, and Macklin, Saskatchewan. As in most lotic systems, discharge values relate directly to precipitation. Discharge in Sounding Creek seems to correlate best with precipitation data of Macklin, while discharge in Monitor Creek seems to correspond more to data of Coronation. There is of course a lag of a few hours between rainfall and discharge.

In 1973, field observations were not made until 20 June, four days after a flood. By this time, water levels had dropped considerably, but there were indications that during the flood previously unassociated ponds west of the study area were connected to stream stations by at least some water (plate 8). Indications were that the water level had been about 1.5 m higher and the stream had completely breached its banks by about 0.5 m. The effect of the flood is further discussed in the chemical and biological sections.

Figure 6 shows detailed discharge data for both Sounding Creek and Monitor Creek during spring runoff. Precipitation values for

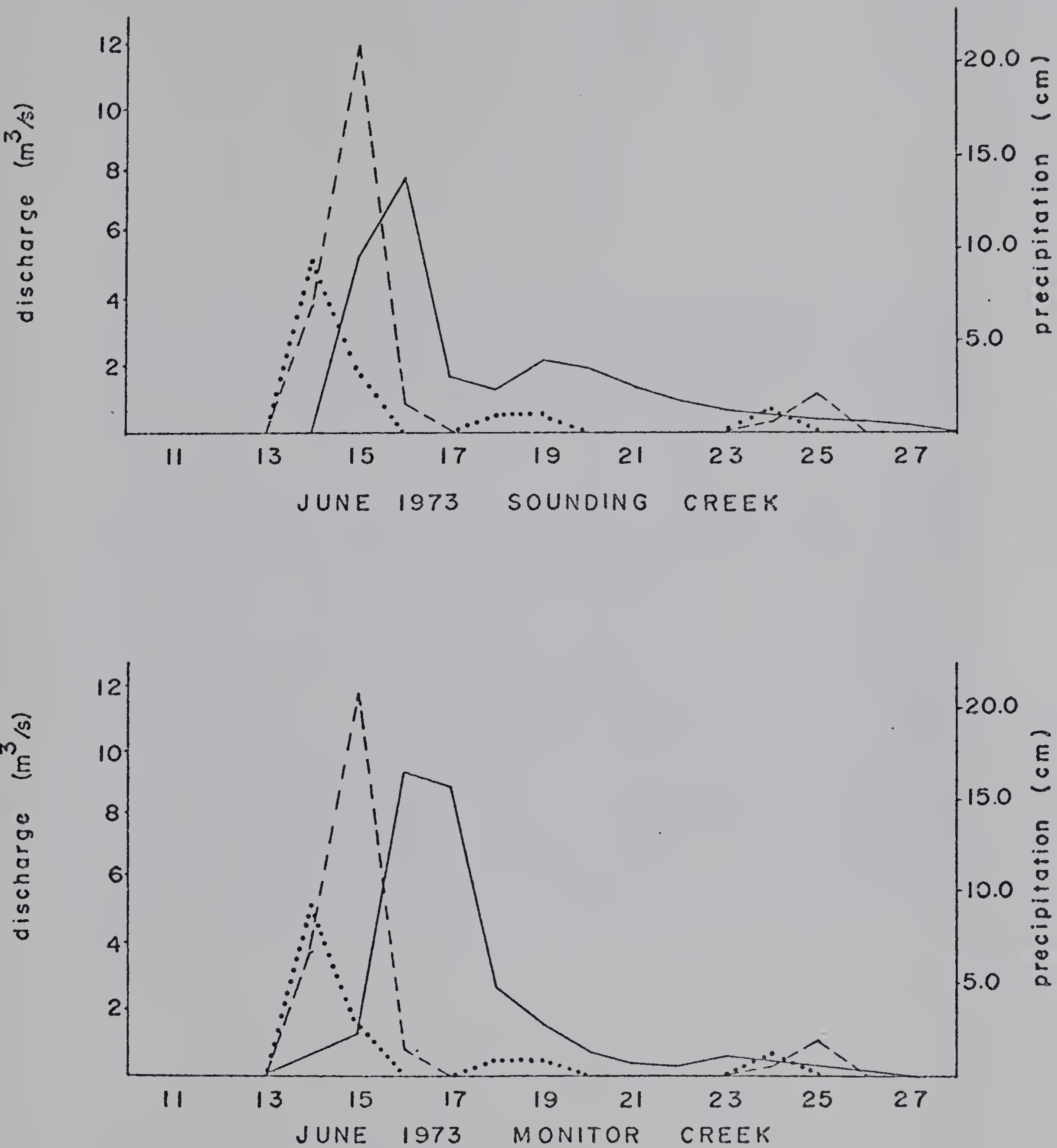

Figure 5. Daily June 1973 discharge in Sounding Creek and Monitor Creek as it relates to precipitation at Coronation, Alberta, and Macklin, Saskatchewan

———— discharge

- - - - precipitation, Coronation, Alberta

· · · · precipitation, Macklin, Saskatchewan

Plate 8. Photograph taken on 20 June 1973, about four days after a flood. The large water body on the left is a portion of the borrow pit mentioned in the text. At this time, water connected the borrow pit to stations 5 and F and the main channel. The viewer is facing northeast.

Plate 8

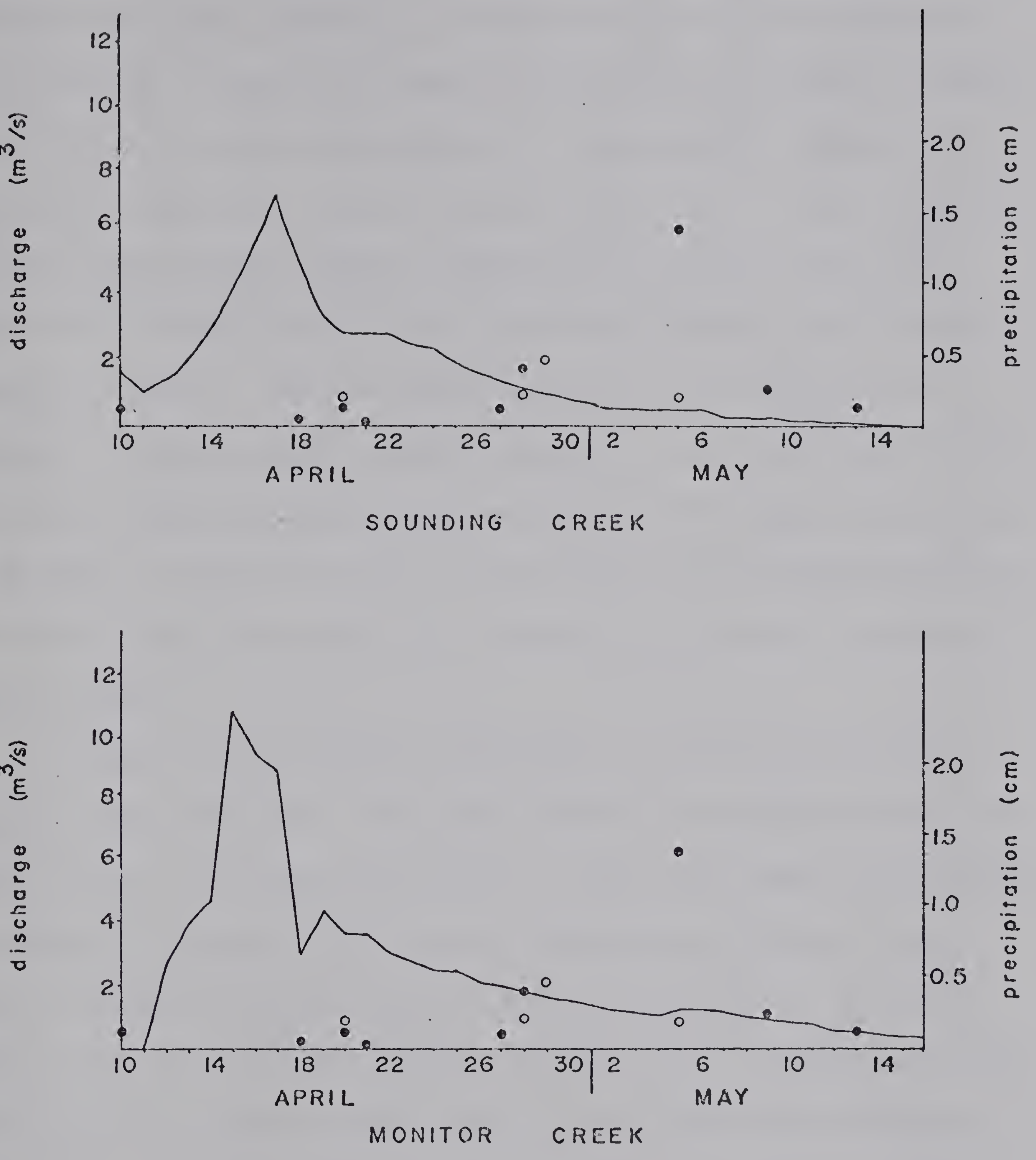

Figure 6. Daily discharge in Sounding Creek and Monitor Creek as a result of spring runoff, 1971

o - precipitation, Macklin, Saskatchewan

● - precipitation, Coronation, Alberta

Macklin and Coronation are included to show that precipitation has little influence on spring discharge. A detectable flow was maintained by melt water for a longer time than was maintained by rainfall. Monitor Creek occupies a narrow, deep valley and consequently temperatures sufficient to melt the ice and snow are attained at a later date than Sounding Creek, which occupies a shallow, wide, unprotected valley (Table 7). In 1968, flow was first observed in Monitor and Sounding Creeks on 1 March. This was due to unusually warm weather in late February. Normal seasonal weather returned in the second week of March and Monitor Creek froze and stopped flowing. Water began flowing again on 24 March. This cold weather did not affect the flow characteristics of Sounding Creek (near Oyen) where spring melt proceeded uninterrupted after 1 March.

Figures 7 and 8 summarize discharge for Sounding Creek and Monitor Creek, 1968-1973. The large increase in discharge during June, 1973 is due to the flood at this time. Water level data are summarized in Figure 9. Generally all stations show similar changes in water level. Because of beaver activity, water level data were available only as long as the depth stakes were left in their original position. Destruction of stakes is indicated by an X on the graphs in Figure 9.

Turbidity

Sounding Creek can be regarded as a turbid stream, with most stations usually exceeding 20 Jackson Turbidity Units (JTU) (Table 8). There was considerable variation in turbidity throughout the sampling period, e.g., from a low of 10 JTU (16 August 1972) to a high of 650 JTU (1 August 1973). Unlike Moore (1951) who found that turbidity increased

Table 7. Date of first measurable discharge for Sounding Creek and Monitor Creek. Numbers in parentheses are the discharge values for that date in cubic meters per second.

Date	Sounding Creek	Monitor Creek
1968	March 1 (0.036)	March 1 (3.02)
		March 24 (0.014)
1969	No data	April 7 (5.43)
1970	March 26 (0.84)	April 6 (0.49)
1971	April 8 (0.84)	April 11 (0.15)
1972	March 23 (0.014)	March 25 (0.008)
1973	March 16 (0.28)	March 21 (0.12)

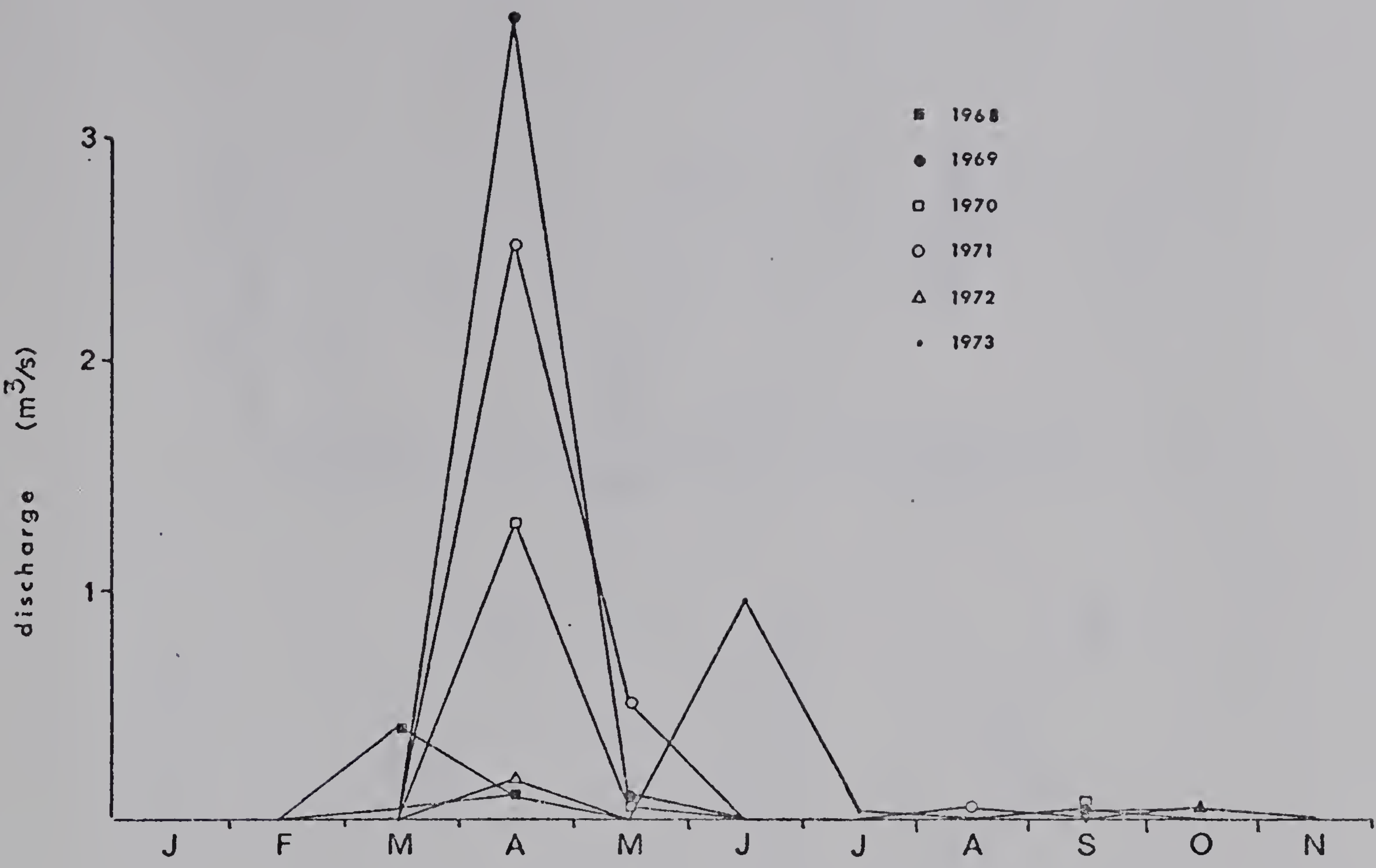

Figure 7. Mean monthly discharge (cubic meters per second) for Monitor Creek at the Town of Monitor.

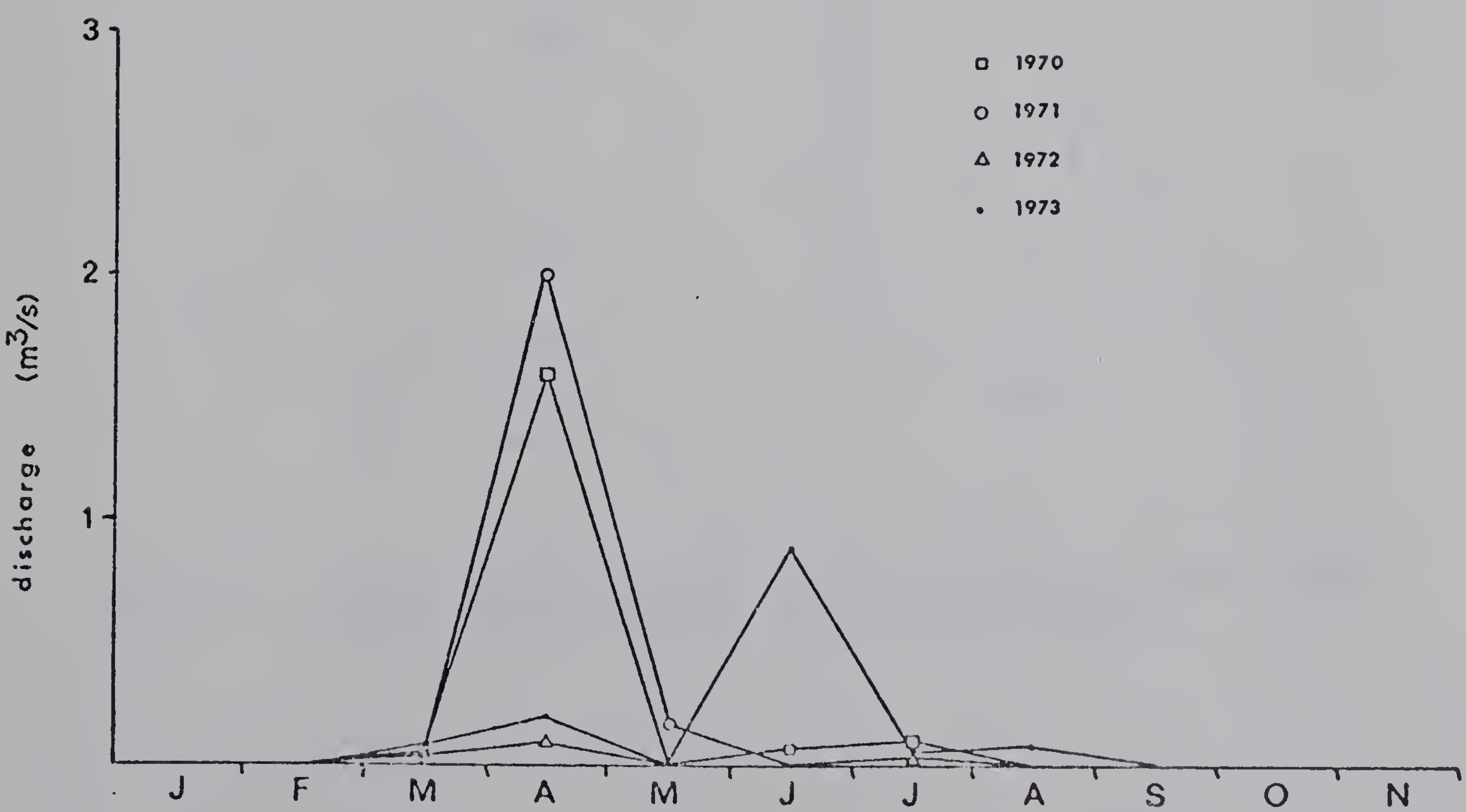

Figure 8. Mean monthly discharge (cubic meters per second) for Sounding Creek at Oyen, Alberta

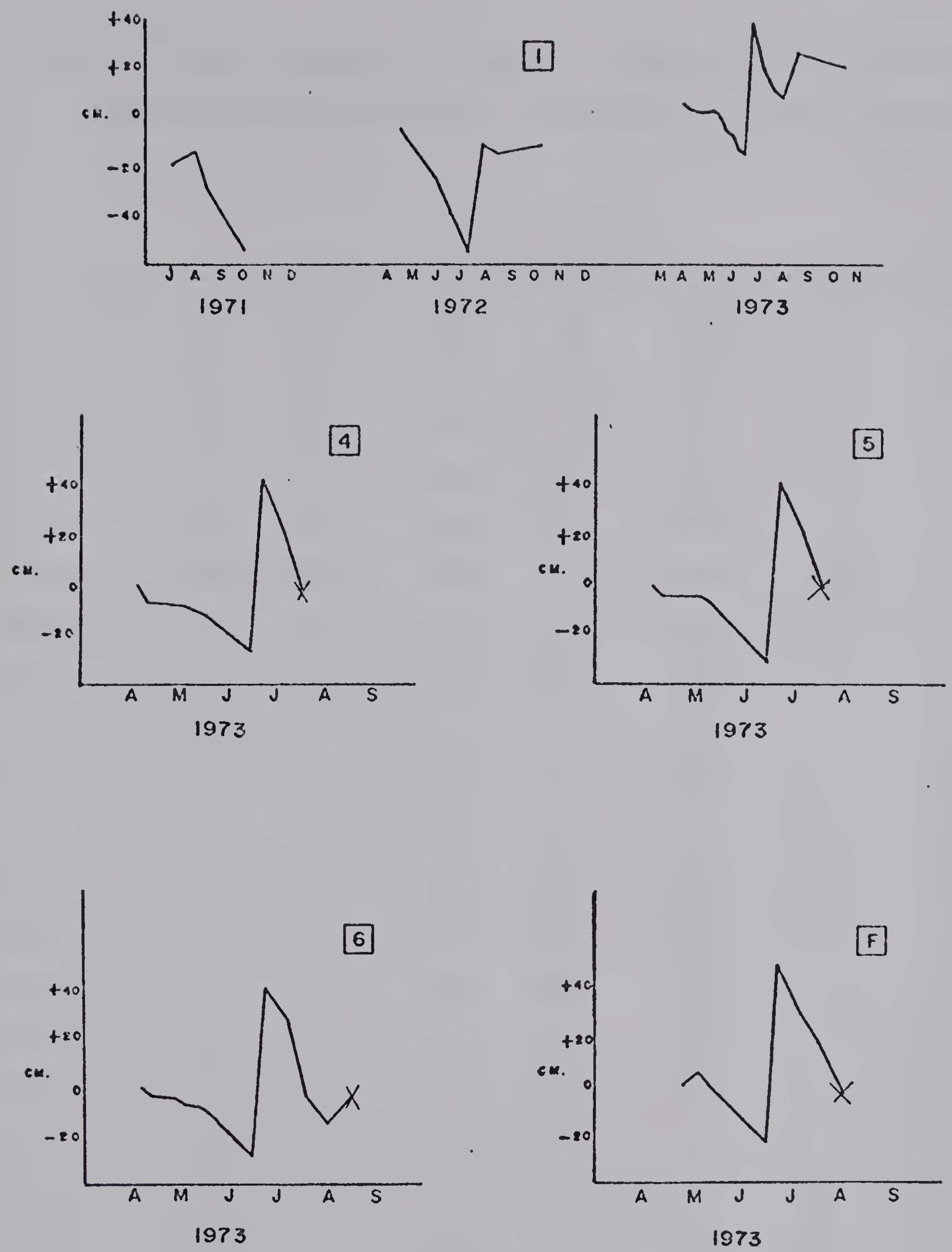

Figure 9. Relative water level data for Sounding Creek. See Materials and Methods for further details.

Table 8. Seasonal changes in turbidity (Jackson Turbidity Units) for Sounding Creek water, 1972 and 1973. (xxx indicates dry station)

Date	Station 1	2	3	4	6	5	F
04/19/72	66	63	80	72	72	30	-
05/3/72	51	42	80	45	40	21	-
05/25/72	39	44	78	40	51	29	-
06/16/72	30	37	xxx	28	35	15	-
07/7/72	27	15	xxx	30	xxx	22	-
07/27/72	310	360	360	375	330	350	-
08/16/72	30	30	90	10	12	20	-
10/7/72	75	100	125	100	118	47	-
12/28/72	92	-	-	-	-	-	-
04/15/73	68	-	71	72	72	40	32
04/25/73	54	-	64	60	61	23	19
05/2/73	61	-	59	66	65	31	26
05/9/73	63	-	72	68	69	19	19
05/16/73	51	-	88	81	210	17	20
05/22/73	51	-	59	55	60	21	17
05/30/73	51	-	39	29	34	23	17
06/7/73	58	-	34	33	41	28	23
06/13/73	55	-	41	28	24	28	23
06/20/73	128	-	130	130	137	96	92
07/5/73	210	-	220	220	150	140	93
07/17/73	460	-	460	455	450	132	66
08/1/73	550	-	550	650	550	68	53
08/15/73	87	-	183	200	210	230	60
10/13/73	100	-	98	72	83	115	125

as the dry season progressed, I found that turbidity in Sounding Creek exhibited a subtle clearing trend. Turbidity in Sounding Creek was directly related to discharge and maintained relatively low levels throughout the year except for periods of floods (27 July 1972 and 20 June 1973).

Turbidity values at each station seemed to fluctuate independently of the other stations but the same trends were maintained. These independent fluctuations were probably a function of differing evaporation rates and isolated instances of disturbance by cattle. However, the silt in Sounding Creek is so fine that even a minor disturbance can cause an obvious increase in turbidity. I observed the conchostracan *Cyzicus mexicanus* causing distinct silt clouds during feeding activity, and large populations of phyllopods, as observed in Sounding Creek in the early part of the sampling year, could also conceivably be responsible for maintaining a turbid state.

Dissolved Oxygen

The 1973 oxygen levels seemed to have been maintained at low levels throughout the winter (station 1) but increased rapidly in spring (Figure 10). Thereafter, a gradual decline led to nearly depleted levels in August and October. Percent saturation followed oxygen concentration very closely, ranging from about 100% to 0% (Table 9). The gradual decrease in dissolved oxygen and percent saturation over the summer is accounted for by the gradual stagnation of the system. Periodic algae blooms (*Spirogyra*) possibly caused reversal of the downward trend (August 1, 1973, 5 and F). Although hydrogen sulphide was not measured, the odor from this gas obviously increased throughout

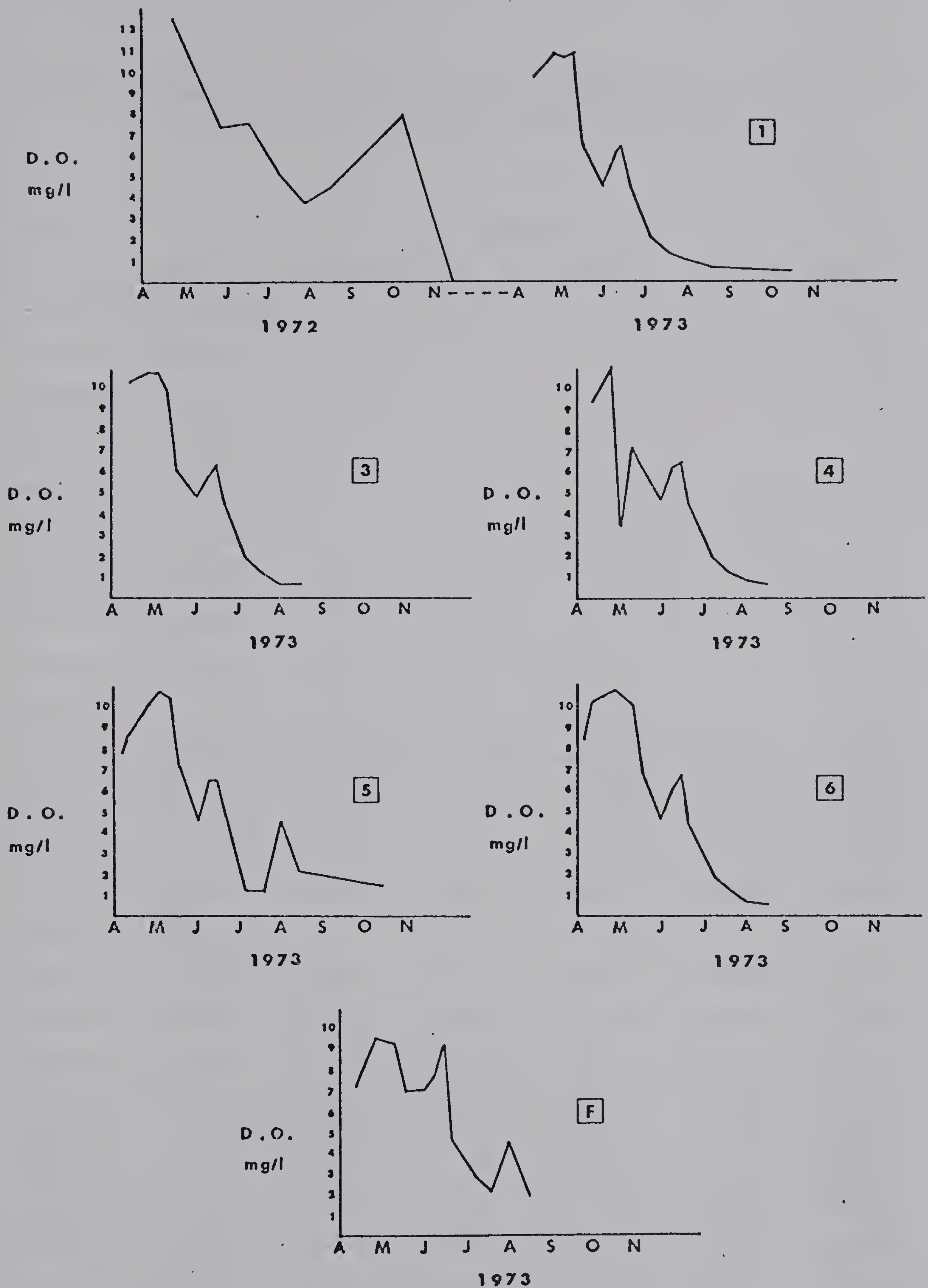

Figure 10. Seasonal trends in dissolved oxygen, Sounding Creek, 1973

Table 9. Seasonal changes in oxygen concentration (mg/l) and percent saturation for Sounding Creek, 1972 and 1973

Date	Station 1 mg/l %	3 mg/l %	4 mg/l %	6 mg/l %	5 mg/l %	F mg/l %
04/19/72	12.6-108	-	-	-	-	-
05/3/72	10.7-96	-	-	-	-	-
05/25/72	7.4-71	-	-	-	-	-
06/16/72	7.5-82	-	-	-	-	-
07/7/72	5.2-53	-	-	-	-	-
07/27/72	3.7-39	-	-	-	-	-
08/16/72	4.5-50	-	-	-	-	-
10/7/72	7.9-69	-	-	-	-	-
12/28/72	O - O	-	-	-	-	-
04/15/73	-	-	-	-	-	-
04/25/73	10.9-103	10.7-101	11.1-105	10.7-101	10.2-98	9.5-91
05/2/73	10.7-102	10.7-102	3.5-33	10.4-100	10.7-102	9.3-85
05/9/73	10.9-103	9.7-92	7.2-69	10.0-97	10.4-100	9.3-90
05/16/73	6.5-70	6.0-64	6.3-71	6.9-73	7.2-76	6.9-77
05/22/73	-	-	-	-	-	-
05/30/73	4.6-51	4.8-55	4.7-52	4.6-51	4.6-51	7.0-77
06/7/73	6.0-62	5.8-60	6.2-66	6.1-65	6.5-67	7.7-80
06/13/73	6.4-71	6.3-71	6.5-75	6.8-76	6.5-72	9.2-104
06/20/73	4.3-45	4.4-48	4.4-48	4.4-48	4.7-52	4.6-50
07/5/73	2.0-22	1.9-20	1.9-21	1.8-20	1.2-12.5	2.9-31
07/17/73	1.3-13	1.2-12	1.2-12	1.2-12	1.2-12	2.1-22
08/1/73	1.0-11	0.7-7.5	0.8-8.5	0.6-5.5	4.5-57	4.5-57
08/15/73	0.7-7.5	0.6-6.0	0.6-6.0	0.5-5.0	2.1-25	1.9-23
10/13/73	0.5-2.0	-	-	-	1.4-10	-

summer and autumn and was particularly evident on 28 December 1972.

Hydrogen Ion Concentration

Sounding Creek has alkaline water, the pH fluctuating between 8.0 and 8.9 except for a few periods of heavy rain (Table 10), when levels dropped below 8.0. Unlike most other chemical components, the hydrogen ion concentration exhibited little seasonal fluctuation.

Hardness and Alkalinity

Alkalinity of Sounding Creek is caused mainly by the bicarbonate ion, the carbonate fraction occurring only rarely (Table 11). Alkalinity fluctuated inversely with discharge. Maximum total alkalinity was recorded on 13 June 1973 (665 mg/l) and the lowest value recorded was on 27 July 1972, shortly after a major rainfall. Carbonate alkalinity ranged from 0 to 37.1 mg/l and generally fluctuated in the same manner as total alkalinity.

Hardness exhibited the same general pattern as that of alkalinity (Appendix 2 and 3). Calcium and magnesium ratios ranged from 0.64, 15 April 1973 at station 6, to 4.5, 9 May 1973 at station 3. No apparent trend was noted and all stations appeared to fluctuate independently of each other (Table 12). Total hardness increased from 180 to 200 mg/l at station F, as a result of the gravel pit overflow. The calcium/magnesium ratio decreased from 1.2 to 1.04 at this time indicating that the gravel pit was richer in magnesium than in calcium.

Measurements of calcium ions by the Department of the Environment indicate that calcium continued to increase in concentration throughout the winter. On 3 August 1973 the concentration was 42 mg/l and on

Table 10 Seasonal changes in hydrogen ion concentration for Sounding Creek water, 1972 and 1973.

Date	Station 1	3	4	6	5	F
04/19/72	8.7	-	-	-	-	-
05/3/72	8.7	-	-	-	-	-
05/25/72	8.7	-	-	-	-	-
06/16/72	9.0	-	-	-	-	-
07/7/72	8.3	-	-	-	-	-
07/27/72	7.5	-	-	-	-	-
08/16/72	7.9	-	-	-	-	-
10/7/72	8.4	-	-	-	-	-
12/28/72	8.6	-	-	-	-	-
04/15/73	-	-	-	-	-	-
04/25/73	8.12	8.40	8.01	8.22	7.52	7.53
05/2/73	8.39	8.80	8.58	8.61	8.31	7.90
05/9/73	8.40	8.57	8.56	8.55	8.28	8.18
05/16/73	8.19	7.90	8.10	7.71	8.10	7.95
05/22/73	8.39	8.30	8.28	8.28	7.93	7.86
05/30/73	8.34	8.09	8.51	8.31	7.93	8.26
06/7/73	8.88	8.67	8.65	8.68	8.12	8.33
06/16/73	8.53	8.70	8.85	8.78	8.15	8.01
06/20/73	7.63	7.72	7.54	7.70	8.48	8.51
07/5/73	7.87	7.85	7.90	8.03	7.80	8.19
07/17/73	8.00	7.90	7.98	7.97	8.28	8.43
08/1/73	8.28	8.15	8.46	8.21	8.96	8.80
08/15/73	8.68	8.40	8.58	8.45	8.60	8.40
10/13/73	8.28	8.36	8.42	8.19	8.30	8.00

Table 11. Seasonal changes in alkalinity (mg/l) for Sounding Creek, 1972 and 1973. a, phenolphthalein alkalinity, b, total alkalinity

Date	Station					
	1	3	4	6	5	F
	a b	a b	a b	a b	a b	a b
04/19/72	0- 170	-	-	-	-	-
05/3/72	12-213	-	-	-	-	-
05/25/72	10-320	-	-	-	-	-
06/16/72	29-423	-	-	-	-	-
07/7/72	0-473	-	-	-	-	-
07/27/72	0-100	-	-	-	-	-
08/16/72	0-290	-	-	-	-	-
10/7/72	6-377	-	-	-	-	-
12/28/72	0-720	-	-	-	-	-
04/15/73	-	-	-	-	-	-
04/25/73	0-191	3-191	0-185	0-189	0-138	0-103
05/2/73	1-198	10-208	6-205	5-206	1-162	0-120
05/9/73	2-226	4-242	6-239	4-238	0-183	0-138
05/16/73	0-247	0-285	0-282	0-271	0-219	0-161
05/22/73	5-290	0-348	0-339	0-308	0-256	0-288
05/30/73	1-302	0-440	9-408	8-395	0-301	0-205
06/7/73	13-334	12-532	20-482	21-479	0-342	2-226
06/13/73	13-350	22-665	37-527	35-372	0-539	0-234
06/20/73	0-121	0-120	0-119	0-130	8-251	8-254
07/5/73	0-229	0-231	0-232	0-254	0-263	0-304
07/17/73	0-270	0-275	0-270	0-276	0-340	7-376
08/1/73	0-346	0-338	8-337	0-338	33-409	20-430
08/15/73	13-374	6-364	11-366	6-367	13-365	6-419
10/13/73	0-429	4-464	9-485	0-520	0-529	0-515

Table 12. Seasonal changes in the magnesium:calcium ion ratio in Sounding Creek water, 1972 and 1973

Date	Station 1	2	3	4	6	5	F
04/19/72	1.13	0.89	1.01	0.92	0.89	0.77	-
05/3/72	1.18	1.04	0.98	1.08	0.95	0.75	-
05/25/72	0.77	1.03	1.51	1.17	1.02	0.88	-
06/16/72	0.98	0.93	-	1.47	1.00	0.73	-
07/7/72	1.76	1.48	-	1.00	-	3.44	-
07/27/72	0.91	0.57	1.00	0.65	0.92	0.83	-
08/16/72	0.86	0.73	1.25	1.12	1.15	0.49	-
10/7/72	0.66	1.19	1.02	0.83	1.06	1.09	-
12/28/72	1.04	-	-	-	-	-	-
04/15/73	1.00	-	0.82	1.00	1.54	0.82	1.07
04/25/73	1.00	-	1.05	0.84	0.74	0.76	1.44
05/2/73	0.57	-	0.53	0.81	0.76	0.83	0.93
05/9/73	0.77	--	0.22	1.00	1.04	0.72	0.57
05/16/73	0.68	-	0.72	0.80	0.91	0.72	0.70
05/22/73	0.67	-	0.77	0.88	1.00	0.88	0.73
05/30/73	0.66	-	0.83	0.92	0.68	0.72	0.64
06/7/73	0.80	-	0.85	0.93	1.13	0.43	0.72
06/13/73	0.77	-	0.93	0.88	1.03	0.76	0.83
06/20/73	0.70	-	0.70	0.67	0.93	0.96	0.96
07/5/73	0.94	-	0.76	1.00	0.90	0.91	0.83
07/17/73	1.20	-	0.90	0.65	1.19	0.80	0.60
08/1/73	1.05	-	1.16	1.26	1.51	0.96	0.77
08/15/73	1.13	-	0.65	0.64	0.95	0.57	0.64
10/13/73	0.91	-	1.23	0.92	0.94	1.00	0.70

15 February 1974, the concentration was 141 mg/l. These increases are perhaps due to the salting-out effect of ice, a phenomenon also noted by Daborn and Clifford (1974).

Salinity Relationships

The definition of salinity can be a point of contention among limnologists and can account for problems associated with data interpretation. Mahlis *et al.* (1970), amongst others, recognize salinity as being equated to chlorinity. This interpretation is commonly used in the marine field. McCarraher (1972), on the other hand, equates salinity to specific conductance. Most limnologists (e.g., Pionke *et al.*, 1972) equate salinity to TDS (total dissolved solids or total residue), which includes not only those compounds that contribute to true salinity (chlorides of magnesium, calcium, sodium and potassium), but also other associated forms, such as sulphates and nitrates. Because of this, chlorinity is not a satisfactory measurement of salinity in inland athalassic water bodies (those with a salinity different in composition from that of ocean salinity). Measurement of TDS would seem to give the best indication of salinity in inland waters. It is a routine measurement, will measure total ionic content, and is applicable to any chemical assemblage. Having measured TDS, specific chemical tests can be carried out to determine the dominant ions.

Most North American saline waters are not predominantly chloride waters. Of the 215 North American lakes listed in McCarraher (1972), only 38, all located in the arid mid-west United States, are predominantly chloride. Of those listed from Alberta, only one is a chloride lake, the remainder being sodium sulphate lakes. The saline

lakes of Saskatchewan are much the same as those of Alberta, predominantly sodium or magnesium sulphate. The major cation in Sounding Creek was sodium (Table 13). Sulphate data obtained for 1972 and 1973 are summarized in Table 14. Sulphate values, as was true for most other chemicals, were inversely related to discharge. The maximum sulphate reading (2180 mg/l) was recorded on 15 February 1974 and, as would be expected, was probably due to a salting-out effect. The minimum reading (150 mg/l) occurred after the flood in 1972 (station 5) and at breakup (station F) on 26 April 1973. The chloride content of Sounding Creek water never exceeded 113 mg/l (7 July 1972--station 4), and rarely exceeded 25 mg/l (Table 15). It appears that the gravel pit to the west of the study area contributes considerably to the ionic content of stations 5 and F. Maximum and minimum chloride contents were 113 mg/l (15 February 1974 at station 1) and 3.76 mg/l (20 June 1973 at station 1).

Total dissolved solids data are summarized in Table 16. The trend towards increased concentration as a result of decreasing water levels is again apparent. Other chemistry data are summarized in Appendix 4. Most of these data come from the Department of the Environment, Water Survey Branch in Calgary, Alberta.

BIOLOGICAL CHARACTERISTICS

Algae

Three algal blooms were observed during the study period. In 1972 *Aphanizomenon flos-aquae* occurred in bloom proportions on 7 July 1972. Small rafts of *Aphanizomenon* were noted in midsummer 1973, but no bloom occurred. Shortly after the 7 July 1972 bloom, a flood occurred

Table 13. Sodium and potassium content of Sounding Creek waters

Date	Station	Sodium	Potassium
06/20/73	1	70	11
	3	92	12
	4	85	12
	6	87	12
	5	>100	15
	F	>100	15
07/17/73	1	>100	20
	3	>100	20
	4	>100	22
	6	>100	22
	5	>100	16
	F	>100	17
08/03/73	1	240	16
02/15/74	1	1210	30

Table 14. Sulphate content (mg/l) of Sounding Creek waters

Date	Stn 1	Stn 3	Stn 4	Stn 6	Stn 5	Stn F
04/19/72	250	390	250	260	190	X
05/03/72	330	450	430	410	300	X
05/25/72	410	1350	500	320	410	X
06/16/72	330	DRY	920	560	500	X
07/07/72	300	DRY	880	DRY	380	X
07/27/72	210	220	260	200	180	X
08/16/72	360	500	450	480	150	X
10/07/72	740	700	660	760	420	X
12/28/72	1650	-	-	-	-	-
04/15/73	380	340	380	360	312	200
04/26/73	380	375	370	390	225	150
05/02/73	440	420	475	450	370	262
05/09/73	480	474	524	520	310	275
05/16/73	540	510	460	500	364	280
05/22/73	540	560	575	525	400	287
05/30/73	475	620	625	615	460	330
06/07/73	600	660	680	690	510	350
06/13/73	600	560	720	740	524	360
06/20/73	380	362	370	365	670	695
07/05/73	435	400	400	480	500	475
07/17/73	330	290	290	275	500	625
08/01/73	280	265	325	330	510	495
08/15/73	630	420	440	400	475	420
02/15/74	2180	X	X	X	X	X

Table 15. Chloride content (mg/l) of Sounding Creek waters

Date	Stn 1	Stn 3	Stn 5	Stn 6	Stn 5	Stn F
04/19/72	8.33	10.03	10.95	10.52	8.08	X
05/03/72	14.30	14.79	13.57	12.01	9.57	X
05/25/72	16.98	35.68	22.89	16.23	12.58	X
06/16/72	22.70	DRY	41.70	26.30	17.90	X
07/07/72	24.20	DRY	44.70	DRY	15.60	X
07/27/72	9.25	9.25	7.80	8.51	5.10	X
08/16/72	11.45	17.55	16.84	15.85	8.05	X
10/07/72	17.40	18.80	19.50	19.80	17.00	X
12/28/72	33.68	-	-	-	-	-
04/15/73	10.63	10.88	10.42	9.93	9.46	8.05
04/26/73	11.34	10.42	10.88	10.42	8.05	6.63
05/02/73	11.84	11.84	11.84	12.30	9.46	7.55
05/09/73	15.14	14.21	13.72	14.21	10.42	9.00
05/16/73	15.14	14.21	15.14	15.63	10.88	9.00
05/22/73	16.55	16.55	17.51	15.63	13.25	9.93
05/30/73	17.05	19.43	19.89	28.43	13.72	10.88
06/07/73	18.93	22.26	21.30	21.80	14.21	10.42
06/13/73	19.18	22.72	25.56	24.14	15.63	10.42
06/20/73	3.76	4.25	4.25	5.21	14.68	14.21
07/05/73	11.34	11.34	11.34	12.30	14.68	15.14
07/17/73	17.51	16.55	17.05	17.05	19.89	21.80
08/01/73	22.04	21.09	21.33	21.80	20.38	20.85
08/15/73	15.63	16.09	16.09	17.05	17.05	19.18

Table 16. Seasonal changes in total dissolved solids (mg/l) in Sounding Creek water, 1972 and 1973. xxx indicates totally frozen stations.

Date	Station 1	2	3	4	6	5	F
04/19/72	612	655	680	644	665	469	-
05/3/72	929	775	934	865	835	608	-
05/25/72	1033	1015	2849	1425	913	895	-
06/16/72	1136	1142	DRY	1861	1332	1116	-
07/7/72	1169	913	DRY	2077	DRY	943	-
07/27/72	698	642	600	655	645	563	-
08/16/72	848	925	1307	1079	1012	460	-
10/7/72	1208	1284	1458	1265	1395	935	-
12/28/72	1994	XXX	XXX	XXX	XXX	XXX	XXX
04/15/73	613	-	617	637	615	490	368
04/25/73	588	-	674	670	656	463	319
05/2/73	748	-	772	760	752	554	445
05/9/73	792	-	847	838	822	572	434
05/16/73	852	-	903	907	995	673	481
05/22/73	924	-	1045	1005	943	742	541
05/30/73	968	-	1189	1083	1122	738	596
06/7/73	1098	-	1341	1343	1336	949	654
06/13/73	1042	-	1341	1404	1386	958	635
06/20/73	610	-	602	605	640	1036	1070
07/5/73	977	-	953	972	988	977	1018
07/17/73	1371	-	1382	1366	1405	1105	1120
08/1/73	1891	-	1894	1965	1855	1116	1153
08/15/73	1128	-	1161	1151	1175	1231	1075
10/13/73	1344	-	1380	1408	1496	1315	1394

and *Aphanizomenon* was not observed again.

During June 1973, two major blooms occurred. At station 4 and to a lesser extent at station 6, *Anabaena* was the dominant algal type. *Mougeotia* was also very abundant at station 6. Large mats of *Mougeotia* and *Anabaena* were found floating on the water's surface or attached to plant stems. *Mougeotia* reappeared in October 1973 and along with *Spirogyra* formed dense mats covering all of station 6 and the littoral area of station 4. *Anabaena*, *Mougeotia* and *Spirogyra* were not found in bloom proportions in 1972.

Macrophytes

There are few species of higher aquatic plants in Sounding Creek, and this is probably due to the temporary nature of the stream. As with the animal community, the lack of species diversity is usually balanced by an increase in quantity of plants of each species.

Following the classification scheme of Lippert and Jameson (1964), the stages of temporary pond plant succession in Sounding Creek are: submerged-flating stage, sedge meadow stage, and grassland-composite stage. In both 1972 and 1973, *Sium suave* and *Sagittaria latifolia* were the most abundant of the submerged aquatic plants at stations 5 and F. Neither plant was present in large numbers in the mainstream. Other submerged or floating plants included *Lemna minor*, *L. trisulca* and *Elodea canadensis*.

The predominant plants of the mainstream stations were *Eleocharis palustris* (creeping spike rush) and *Scirpus validus* (softstem bulrush). A few *Carex* sp. were also present. *Eleocharis* occurred in a thin border along most of the stream, *Scirpus* occurred mainly where the banks

flattened out. Plate 9 shows the distinct plant zonation evident at station F (13 June 1973). Dark green areas are *Eleocharis* while the light green areas are *Sium* and *Sagittaria*. Plate 10 shows the *Scirpus* beds at station 3 and the *Spirogyra-Anabaena-Mougeotia* mats (13 June 1973). In contrast to its effect on the algal organisms, the flood of June 1973 had no appreciable effect on the higher aquatic plant community. *Eleocharis*, together with various types of invading grasses, made up the grassland-composite stage (plate 11).

Annelida

Four species of leeches were recorded from Sounding Creek: *Erpobdella punctata*, *Glossiphonia complanata*, *Theromyzon rude* and *Oculobdella lucida*. *O. lucida* was collected on several occasions and was the most abundant leech in both years. Individuals carrying young were found in July in both 1972 and 1973. *E. punctata* was the only other abundant leech, occurring from April to August. *G. complanata* and *T. rude* were found carrying young on 15 August 1973. Except for one occasion (27 July 1972), leeches were never found at stations 5 and F.

Oligochaetes occurred in about equal numbers at all stations. Two genera of oligochaetes, *Nais* and *Chaetogaster*, were about equally abundant at all stations beginning in mid-May. Oligochaetes were rare before this date and after mid-June. *Chaetogaster* preyed heavily on the cladoceran, *Chydorus sphaericus*.

Zooplankton

Rivers and fast-moving streams do not support very large plankton populations. Most of these rivers maintain only "accidental," or

Plate 9. Plant zonation during late-stage succession, 13 June 1973 (station F)

Plant 10. *Scirpus* beds and algal bloom mats (*Spirogyra*, *Anabaena* and *Mougeotia*), 13 June 1973 (station 3)

Plate 9

Plate 10

Plate 11. Grassland-composite stage, 7 October 1972 (station F)

Plate 11

tychoplankton, populations, introduced from backwater areas or removed from the bottom by the scouring action of water. However, small sluggish streams, especially temporary streams, develop large and diverse planktonic assemblages. Sounding Creek, with its combination of slowly flowing and lentic sections, was rich in both numbers of animals and numbers of species.

Rotifera

The list of provisionally identified rotifers is given in Appendix 1. In Sounding Creek there are only five common species of rotifers: *Keratella cochlearis*, *K. quadrata*, *Brachionus angularis*, *Filinia longiseta* and *Polyarthra vulgaris*. Numbers varied considerably over the two ice-free seasons (Figures 11 and 12). In the spring 1972, *K. cochlearis* was not very abundant, reaching a maximum density of only 1171 animals per liter (station 1). In 1973, however, *K. cochlearis* was the most abundant rotifer at all stations (up to 7051 animals per liter, 30 May 1973). *K. cochlearis* and the unidentified illoricate rotifers were the only rotifers common to all stations in early spring. *K. cochlearis* in Sounding Creek exhibited pronounced cyclomorphosis (posterior spine length and size of lorica). Shortly after the spring thaw of both years there were unidentified illoricate rotifers in Sounding Creek. *Asplanchna* and *Rotaria* are present only in the deeper sections of the stream in early spring.

The occurrence of some species of rotifers appears to be accidental, resulting from extensive summer flooding. In 1972, five species of rotifers, which had previously not been recorded, occurred immediately after the late July flood (Table 17); and three of these,

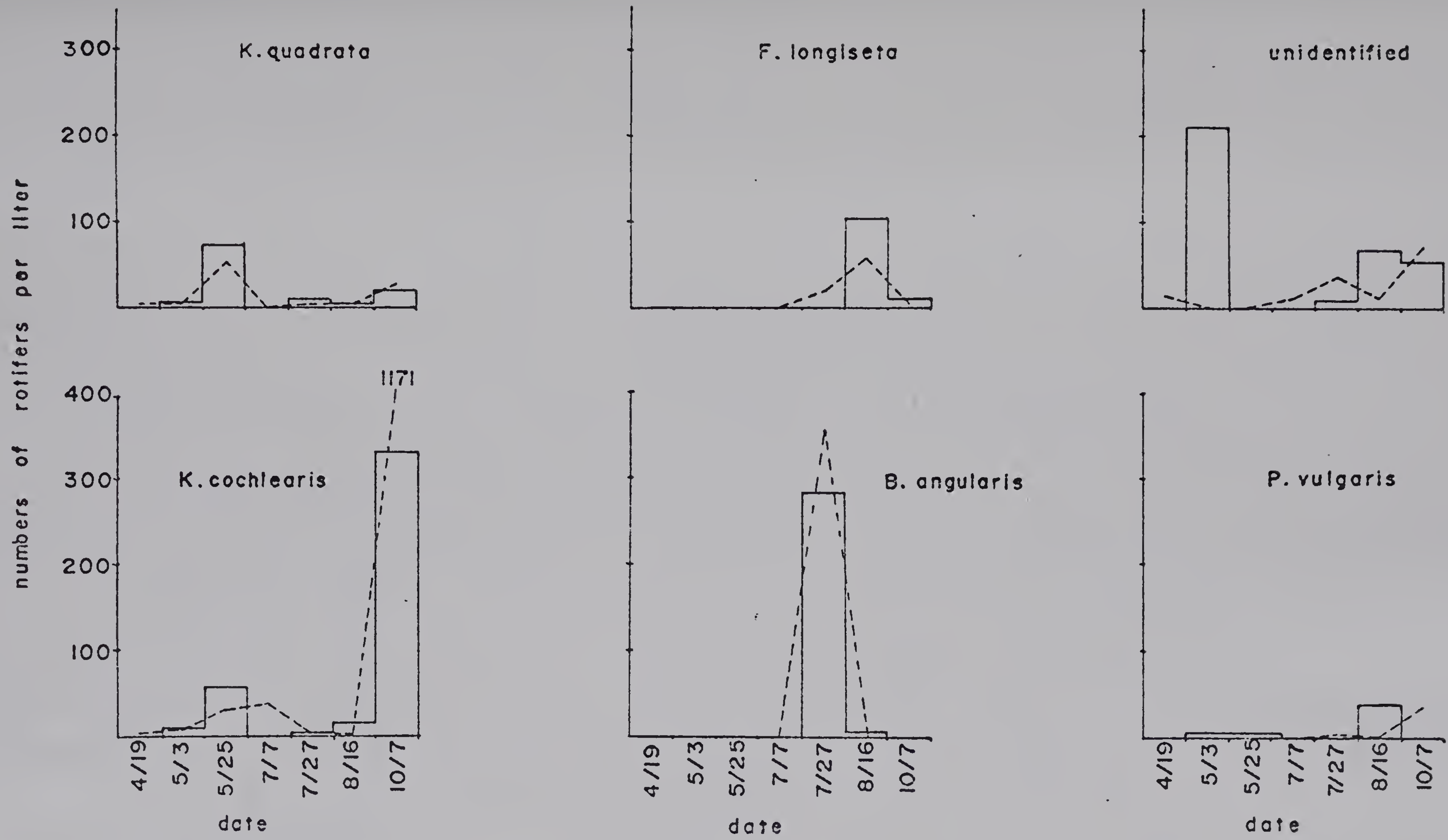

Figure 11. Seasonal abundance of the major species of rotifers in Sounding Creek, 1972 (solid lines - station 1, broken lines - station 2)

Figure 12. Seasonal abundance of the major species of rotifers at Sounding Creek 1973

station 1

station 5

present (station 1) but less than 20/1

present (station 5) but less than 20/1

Date: A - April

M - May

J - June

J - July

A - August

O - October

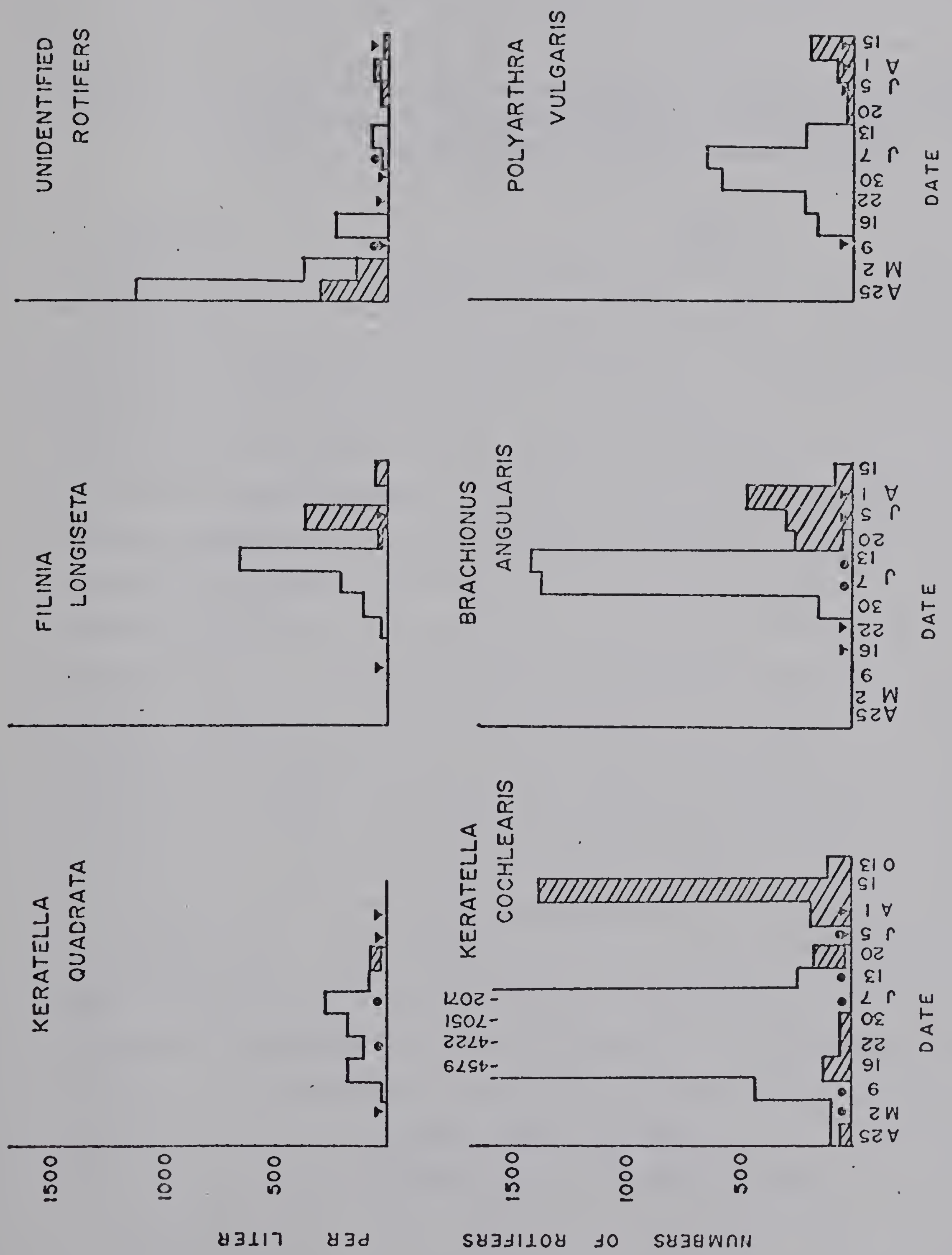
KERATELLA QUADRATA
FILINIA LONGISETA
UNIDENTIFIED ROTIFERS
KERATELLA COCHLEARIS
BRACHIONUS ANGULARIS
POLYARTHRA VULGARIS
NUMBERS OF ROTIFERS PER LITER
1500
1000
500
4579
4722
7051
2071
A25 M 2 9 16 22 30 J 7 13 20 J 5 A 1 15 O 13
DATE

Table 17. Change in rotifer assemblage at station 1, 1972 and 1973. * occurred only before flood; o occurred only after the flood; + occurred before and after the flood.

Rotifer	1972	1973
Asplanchna sp.		*
Brachionus angularis	o	+
Brachionus calyciflorus		*
Brachionus plicatilis	o	o
Branchionus quadridentata	+	o
Filinia longiseta	o	+
Keratella cochlearis	+	+
Keratella quadrata	+	+
Lepadella sp.		o
Notholca acuminata		*
Platyias quadricornis		o
Polyarthra vulgaris	+	+
Pomopholyx sp.	o	
Rotaria sp.	+	+
Testudinella sp.		+
Trichotria sp.	o	
Unidentified rotifers	+	+

1972 flood - 21 July

1973 flood - 14 and 15 June

Brachionus plicatilis, *Trichotria* and *Pomopholyx*, also occurred shortly after the flood of 1973. *B. plicatilis* is distributed mainly in alkaline waters and was thought by Ahlstrom (1940) to be an indicator of brackish water. However, Rawson and Moore (1944) found *B. plicatilis* in only one of 60 Saskatchewan lakes; this was Manito Lake, which is located in the eastern end of the Sounding Creek drainage basin and has a salinity (TDS) of more than 20,000 mg/1.

The effect of the flood on the rotifer fauna was most obvious at stations 5 and F where the number of rotifer species present after the flood increased by 12 and 5 species respectively (Table 18). In contrast, stations in the stream proper (1, 4 and 6) exhibited an increase of only two or three species of rotifers after the flood. The reason for the large increase in diversity at station F and 5 is not fully understood, but it might be due to the influence of the borrow pit to the west.

Klimowicz (1967) and other workers noted that even closely adherent ponds have highly varied faunal assemblages of rotifers, but it seems from my work that faunal assemblages of even interconnected, flowing bodies of water can have quite different faunas.

Brachionus angularis was abundant in the gut of *Asplanchna* and, as noted by Green and Lan (1973), *Asplanchna* might selectively feed on *Brachionus*. Green and Lan also noted that *Filinia longiseta* was a major food item for *Asplanchna*. Although *Filinia* was present in large quantities in the plankton of Sounding Creek, they were rarely observed in *Asplanchna* guts. The cladoceran, *Chydorus sphaericus*, was frequently observed in the gut of *Asplanchna* from Sounding Creek.

Table 18. Rotifer assemblages before and after the flood of June 1973 (* denotes single record)

Rotifer	Before flood					After flood				
	Station number									
	1	4	5	6	F	1	4	5	6	F
Keratella cochlearis	+	+	+	+	+	+	+	+	+	+
Keratella quadrata	+	+	+	+	+	+	+	+	+	+
Brachionus angularis	+	+	+		+	+	+	+	+	+
Brachionus quadridentata		+		+		+	+	+		+
Brachionus bidentata								+		+
Brachionus caudatus										+*
Brachionus plicatilis		+		+	+	+	+	+	+	
Brachionus calyciflorus	+							+		
Notholca acuminata	+	+	+	+						
Filinia longiseta	+				+	+	+	+	+	+
Polyarthra vulgaris	+	+		+	+	+	+	+	+	+
Platyias quadricornis						+		+		
Mytilina sp.								+*		
Testudinella sp.	+	+		+	+	+	+	+	+	+
Lecane sp.		+			+					
Euchlanis sp.				+	+					+
Kellicotia sp.					+*					
Asplanchna sp.	+	+		+	+					+
Colurella sp.								+*		
Trichotria sp.										+*
Monostyla sp.								+*		
Rotaria sp.	+					+	+	+	+	
Pomopholyx sp.										+*
Lepadella sp.				+		+	+	+	+	
Unidentified rotifers	+	+	+	+	+	+	+	+	+	+

Amixis in rotifers was evident through most of the year in Sounding Creek, but signs of mictic reproduction were rarely noted and I found no male rotifers. Male rotifers have life cycles of only a few to several days (Pennak, 1953, and Pilarska, 1972), and it is possible that my sample intervals were not short enough to capture males. Also male rotifers are much smaller than females and may have passed through the plankton netting. On 25 May 1973, *Euchlanis* sp. and *Asplanchna* sp. were found carrying resting eggs, the culmination of mictic reproduction. *Euchlanis* was only found at stations F and 6 (the two most temporary stations).

As found by Wiktor (1968), *K. cochlearis* and some other rotifers were found carrying more than one amictic egg, mainly in the early spring. Although Wiktor found *B. calyciflorus* and *B. angularis* carrying as many as eight and five eggs respectively, females with more than two eggs were never found in Sounding Creek. The greatest percentage of females carrying amictic eggs occurred in spring in the mainstream stations. Amictic reproduction subsequently declined; but after the mid-June flood, 1973, amictic reproduction increased at stations 5 and F, at which time almost all the females were carrying eggs at these stations.

Copepoda

Cyclopoid copepods were abundant in both years in Sounding Creek (Table 19). Three cyclopoid species were identified, but only one, *Cyclops vernalis*, was abundant. *Mesocyclops albidus* and *Eucyclops speratus* accounted for less than 1% of the cyclopoids over the study period. Copepod nauplii (mostly cyclopoid) were abundant for most of

Table 19. Total number of entomostracans per liter, 1972 and 1973. * - 100% cyclopoids or copepod nauplii; + - more than 90% cyclopoids or copepod nauplii

	Station	
Date: 1972	1	2
04-19	-	40
05-03	15*	129+
05-25	60	266
07-07	48	138
07-27	44	34
08-16	313+	60+
10-07	48+	111+

	Station				
Date: 1973	1	4	5	6	F
04-25	25*	38*	2270+	28*	399
05-02	205*	45*	734+	68	956+
05-09	560*	319*	2192+	392*	723+
05-16	980*	---	1839*	607+	887*
05-22	347*	734*	1720+	235+	488+
05-30	1312*	199+	326+	256	175+
06-07	889+	163*	265+	125	962+
06-13	200*	184	144	253	154
06-20	23	21*	158+	49*	---
07-05	164	130	100	113	361+
08-01	1580+	826+	149+	1096+	431
08-15	373+	304+	830*	---	207
10-13	53*	65	30*	36	40*

1973 and showed three peaks of abundance, which corresponded to the peaks of cyclopoid adult abundance. Cyclopoid and copepod nauplii abundance in 1972 was considerably less than 1973.

Harpacticoid copepods were present for much of the year, but they were rarely present in large numbers. Maximum harpacticoid density occurred in spring.

Calanoid copepods, although represented by 10 species, were never very abundant in 1972. In 1973, however, the most common calanoids were *D. eiseni*, *D. nudus* and *D. leptopus*. A few rare species such as *D. forbesi* and *D. sangiuneus* occurred sporadically throughout the year. Calanoids were most abundant in stations 5 and F in 1973. Tables 20 and 21 indicate the succession patterns of the various species of *Diaptomus* and the differences between the 1972 and 1973 seasons. Seasonal occurrence records corresponded well with what Sawchyn and Hammer (1968) found for calanoids in Saskatchewan ponds.

The 1973 flood affected the calanoid species. Two species, *D. forbesi* and *D. sicilis*, were apparently washed into the study area as a result of the flood. As well, infusion of water from all stations provided for more uniform calanoid assemblages. The 1972 flood had no apparent effect on species composition.

Cladocera

There are few papers dealing directly with the ecology of Cladocera in temporary habitats, but numerous authors (Kenk, 1949; Rawson and Moore, 1944; Daborn, 1974; etc.) included Cladocera in their studies of temporary habitats, but only in a minor sense. In some

Table 20. Distribution of *Diaptomus* species in all stations, 1972

Date	Station 1	2	3	4	5	6
A 19	-	-	-	-	-	-
M 3	-	-	-	-	-	-
25	ne sa si so	-	-	-	sa e	sa
Ju 16	-	e	-	-	-	-
Jy 7	so	so	-	-	-	-
27	so	so cp	-	-	-	1
Au 16	-	-	-	-	si	1
O 7	u	so u	-	-	-	-

cl = clavipes
cp = clavipoides
e = eiseni
f = forbesi
1 = leptopus
nu = nudus
ne = nevadensis
sa = sanguineus
si = sicilis
so = siciloides
u = unidentified

Table 21. Distribution of *Diaptomus* species at Sounding Creek, 1973

Date	Station 1	3	4	5	6	F
04/25	-	-	-	u	-	u
05/2	-	-	-	e	-	e
05/9	-	u	-	-	-	e
05/16	-	-	-	e u	-	e sa
05/22	-	-	-	e u	e	e u nu
05/30	-	so	-	e u l	l	e sa l
06/7	u	so	so	e l nu so u	-	l
06/13	u	-	-	e cl l nu so	-	l nu u
06/20	u	u	u si	e si u	e si nu f u	si nu
07/5	-	-	-	-	-	u
07/17	-	-	-	-	-	-
08/1	u	-	-	nu l u	u	nu
08/15	-	-	-	-	-	nu
10/13	-	-	-	-	-	-

cl- <u>clavipes</u> l- <u>leptopus</u> si- <u>sicilis</u>

cp- <u>clavipoides</u> ne- <u>nevadensis</u> so- <u>siciloides</u>

e- <u>eiseni</u> nu- <u>nudus</u> u- unidentified

f- <u>forbesi</u> sa- <u>sanguineus</u>

studies of permanent water bodies of Alberta (Pinsent, 1967; Daborn, 1969; Horkan, 1971; and Gallup, pers. comm.), the authors indicate that the cladoceran fauna, in most cases, rarely exceeded 10 species. Some lakes in the Edmonton area had as few as two or three species. Sounding Creek, as is generally true of most saline, prairie water bodies, had a very diverse cladoceran fauna (at least 26 species), although many of the species were rare.

Periodicity. *Daphnia magna* and *D. pulex* were the first cladocerans to appear in plankton samples (station 1) in 1972. *D. pulex* and to a lesser extent *D. magna* and *Ceriodaphnia affinis* were evident in plankton samples at the end of May. By 7 July *D. magna* was dominant, *D. pulex* only rarely being found. *Macrothrix laticornis* and *Bosmina longrostris* were the only cladocerans present in plankton samples after the mid-July flood.

Chydorus sphaericus, abundant in samples from central Alberta (Pinsent, 1967), was rare in Sounding Creek in 1972, but one of the more common cladocerans at most stations in 1973. *C. sphaericus* was abundant (qualitative) at stations 1, 3, 4 and 6 in spring, but only rarely occurred at stations 5 and F during the second major population peak of late summer.

At station 1, most cladocerans did not occur in large numbers in 1973 until 5 July, which was after the 1973 flood. *Ceriodaphnia affinis* was the most common cladoceran up to a maximum density of 25 animals/ liter, 1 August), although *D. pulex*, *Diaphanosoma brachyurum* and *Alona guttata* were also present. *Simocephalus vetulus* was the dominant cladoceran at station 4 (38/liter, 13 June). *C. affinis* was also a

dominant cladoceran at station 6, reaching a peak population of 111/liter on 30 May. A second peak was noted in August (19/liter). *Chydorus sphaericus* (23/liter, 13 June) and *Bosmina longirostris* (19/liter, 13 June) were the other common cladocerans. *Simocephalus vetulus*, *Daphnia pulex*, *Scapholeberis kingi* and *Alona* spp. were uncommon. *D. pulex* was common at station 5 until the June flood when it disappeared from the plankton samples. *Ceriodaphnia affinis* and *Bosmina longirostris* were the only other abundant cladocerans at station 5. *Simocephalus serrulatus*, *Diaphanosoma brachyurum*, *Scapholeberis kingi* and *Ceriodaphnia affinis* were also present. Only *D. pulex* was present in plankton hauls before the flood at station F. After the flood, *Scapholeberis kingi*, *Chydorus sphaericus*, *Alona costata*, *Bosmina longirostris* and *Diaphanosoma brachyurum* were present in small numbers. Other species listed in the provisional taxon list occurred sporadically or rarely.

Cole (1967) considered *Diaphanosoma* and *Bosmina* to be indicative of permanent water bodies and *D. pulex* and *Moina* spp. to be most common in temporary water. All Cladocera in Sounding Creek, except *S. serrulatus*, are distributed throughout most of my study area. It would seem that most cladocerans exhibit a particular habitat preference but are capable of existing in a variety of habitats, providing the conditions permit completion of the life cycles.

Reproductive cycles. By the beginning of May 1972, *Daphnia pulex* females were carrying eggs, and ephippia had formed by the end of May (Figure 13). Parthenogenetic *D. magna* females were noted as early as 25 May, but males and ephippial females were not found until late June and early July. A second generation of ephippial females of both *D. pulex*

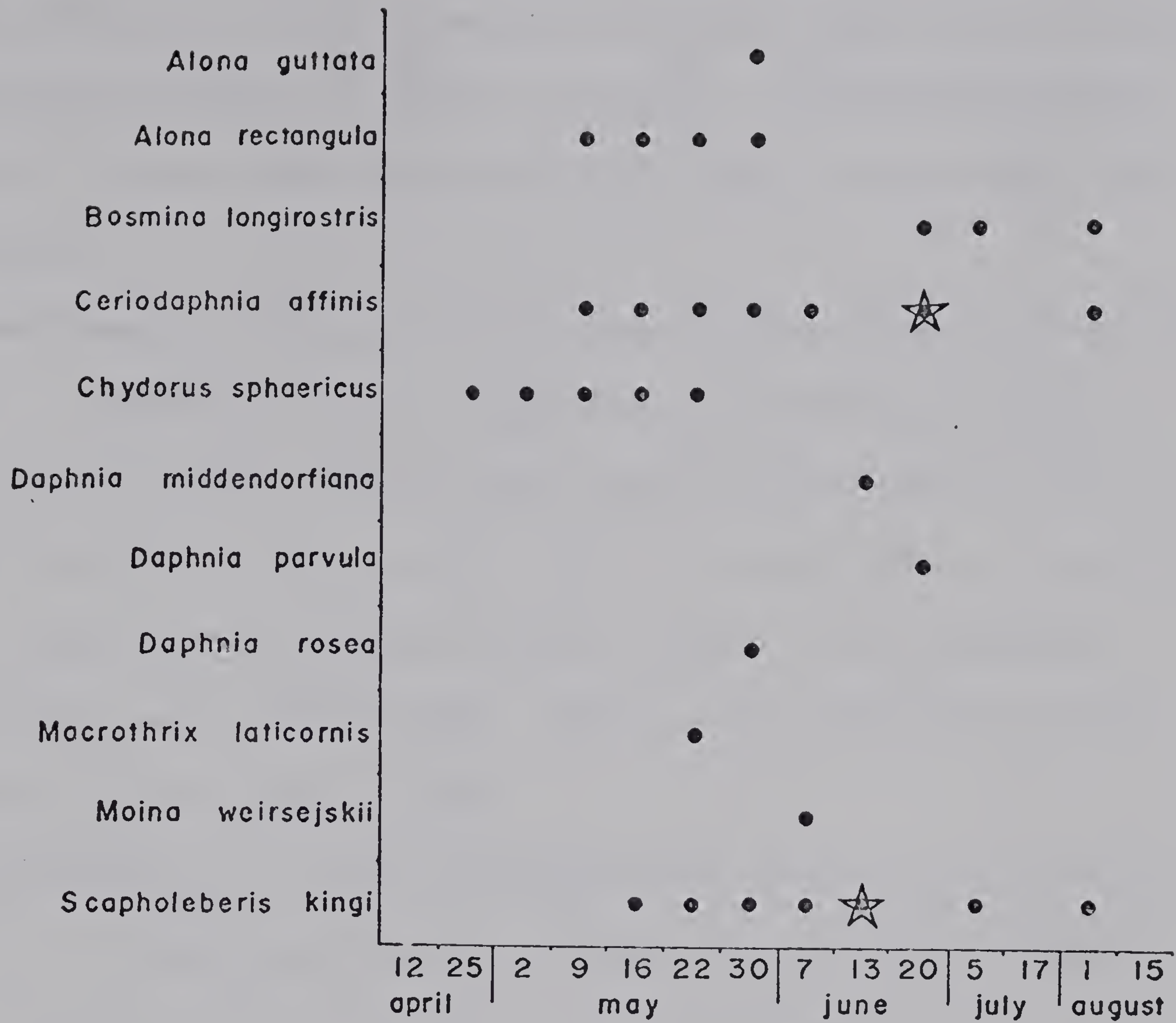

Figure 13. Reproductive stages of some Cladocera in Sounding Creek stations, 1973

● represents parthenogenetic females

☆ represents ephippial females

and *D. magna* was noted in early October. Parthenogenetic female and male *Moina wiersejskii* and parthenogenetic female *Diaphanosoma brachyurum* and *Scapholeberis kingi* were found in late May. *Ceriodaphnia affinis* and *Pleuroxus aduncus* females were found with eggs in late August and early October.

Development of 1973 cladoceran populations proceeded much the same as in 1972. *Daphnia pulex* and *D. magna* females were first observed carrying eggs by mid-May, however males were not found until 30 May. This was considerably earlier than in 1972. A second pulse of parthenogenetic *D. magna* and *D. pulex* was noted in August, but no ephippial *D. magna* females were found in 1973. Eleven other cladoceran species were observed carrying eggs in 1973.

Simocephalus spp. were only abundant for about one month in 1973 (Table 22). *S. vetulus* was the most abundant and was found mainly at stations 1, 3, 4 and 6. *S. vetulus* first occurred on 25 April. *S. serrulatus* did not occur until mid-May and was mainly found at stations 4, 5 and F. As a result of the 1973 June floods, *S. serrulatus* was more widely distributed through the area after 20 June. Parthenogenetic *S. vetulus* females were first observed on 16 May. Ephippial females were first observed on 30 May and were present until 20 June. *S. serrulatus* parthenogenetic females appeared on 22 May. Ephippial females did not appear until 7 June and were present until 17 July. Parthenogenetic females of both *S. vetulus* and *S. serrulatus* were present on August 1. All *Simocephalus* had disappeared by mid-October.

Ephippial females of both *Simocephalus* species were usually about 0.5 mm smaller than parthenogenetic females, but occasionally parthenogenetic females were up to twice as large as ephippial females.

Table 22. Numbers of *Simocephalus vetulus* and *S. serrulatus* in 1973 (+ indicates less than 1)

Date	*S. vetulus*						*S. serrulatus*					
	1	3	4	5	6	F	1	3	4	5	6	F
04-25	+	+	+	4	10	-	-	-	-	-	-	-
05-02	-	-	4	12	16	3	-	-	-	-	-	-
05-09	-	-	3	-	1	2	-	-	-	-	-	-
05-16	-	5	24	-	10	4	-	-	2	-	-	-
05-22	2	46	128	-	265	12	-	-	2	12	-	-
05-30	-	140	1680	-	158	4	-	-	216	14	22	10
06-07	40	-	436	1	-	-	-	-	84	2	-	-
06-13	-	15	42	3	60	8	-	+	+	34	-	12
06-20	3	8	11	60	6	7	-	-	3	8	1	3
07-05	10	-	25	5	4	10	2	-	18	10	8	10
07-17	2	-	16	-	2	1	-	-	14	2	+	17
08-01	-	2	1	3	-	-	-	-	1	9	-	7
08-15	-	-	-	4	-	2	-	-	-	-	-	3
10-13	-	-	-	-	-	-	-	-	-	-	-	-

Effect of flood. The flood that occurred in mid-June, 1973 had a pronounced effect on the cladoceran fauna (Table 23). Of the nine species recorded from all stations just prior to the flood (13 June), only two, *Alona* spp. and *Bosmina longirostris*, were present immediately after the flood (20 June).

Anostraca

Productivity in temporary waters is usually quite high (Hartland-Rowe, 1966). Bacteria and nannoplanktonic algae provide an abundant food supply for a variety of filter feeders. Perhaps the most familiar filter feeding inhabitants of temporary ponds are the fairy shrimp, or phyllopods, which are virtually confined to temporary waters or to habitats with widely fluctuating water levels.

Eubranchipus bundyi and *E. intricatus* are both common inhabitants of temporary waters in Alberta (Hartland-Rowe, 1967; Daborn, 1974), and these two species are the dominant fairy shrimp in the Sounding Creek system. The adult portions of the species' life cycles are shown in Figures 14 and 15. In 1973, adults of *E. bundyi* were first observed in late April. Sexually mature females did not occur until the second week of May. No *E. bundyi* were found after the third week of May. The first adult *E. intricatus* were not observed until the second week of May 1973. Sexually mature females did not occur until the middle of May. The last *E. intricatus* were captured on June 7.

Eubranchipus eggs hatch as soon as the substrate thaws. The presence of very small *Eubranchipus* for long periods in spring of 1973 indicates that hatching may occur over an extended period. Since I could

Table 23. Zooplankton assemblages immediately before and after the June 1973 flood. Data based on quantitative samples.

	Before flood					After flood				
	Station number									
	1	4	5	6	F	1	4	5	6	F
Cyclopoid copepod	+		+	+	+		+	+		+
Copepod nauplii	+	+	+	+	+	+	+	+	+	+
Chydorus sphaericus				+						
Ostracods					+			+		
Daphnia pulex			+							
Daphnia magna		+								
Daphnia sp.				+						
Ceriodaphnia affinis		+								
Simocephalus serrulatus		+	+							
Simocephalus vetulus		+								
Scapholeberis kingi				+						
Alona spp.				+		+				
Bosmina longirostris			+	+						+
Diaptomus leptopus			+							
Diaptomus nudus					+					
Unidentified *Diaptomus*					+					+

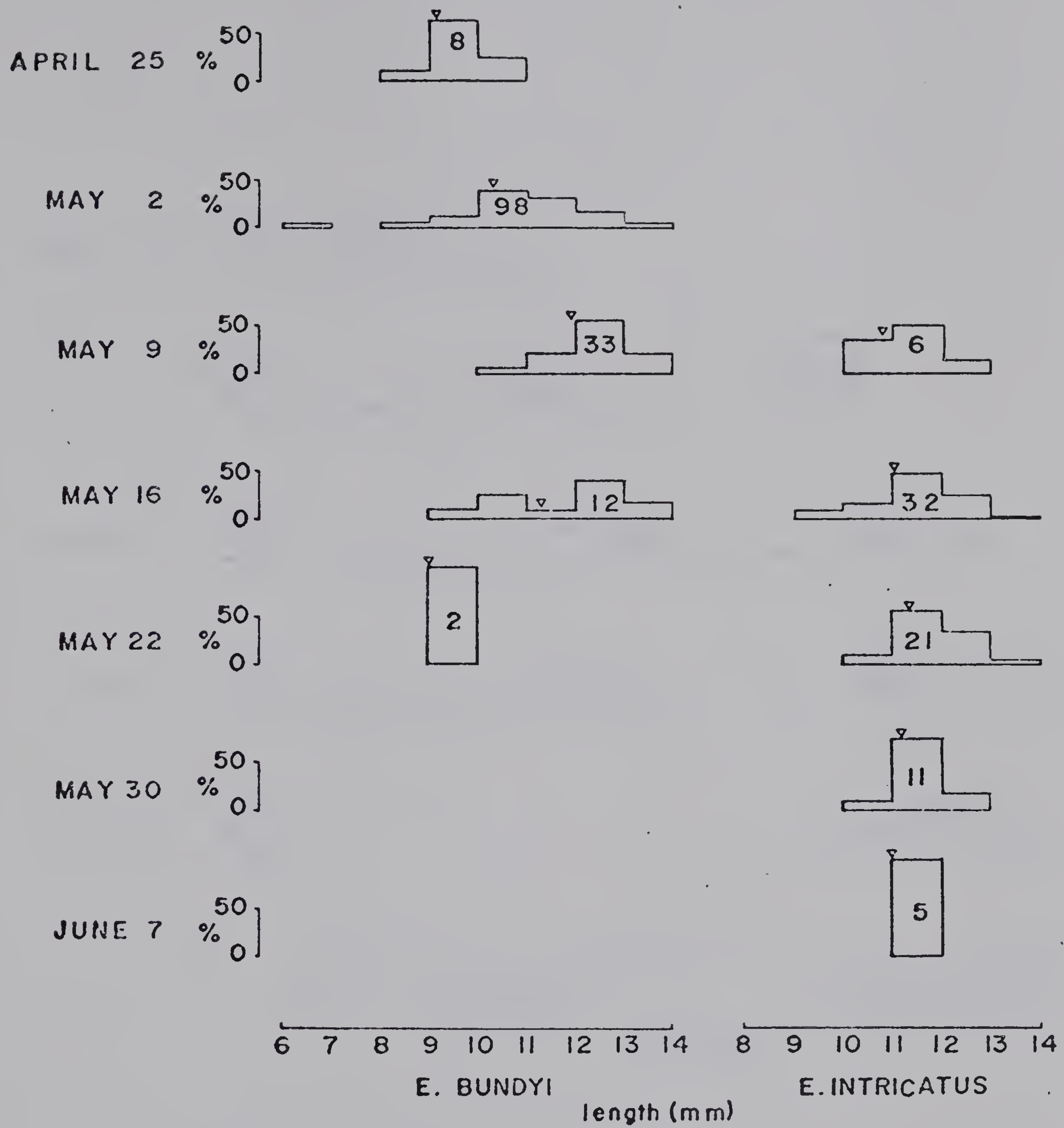

Figure 14. Population length-frequency histogram for *Eubranchipus bundyi* and *E. intricatus* males (station 5), 1973. Arrow indicates mean size.

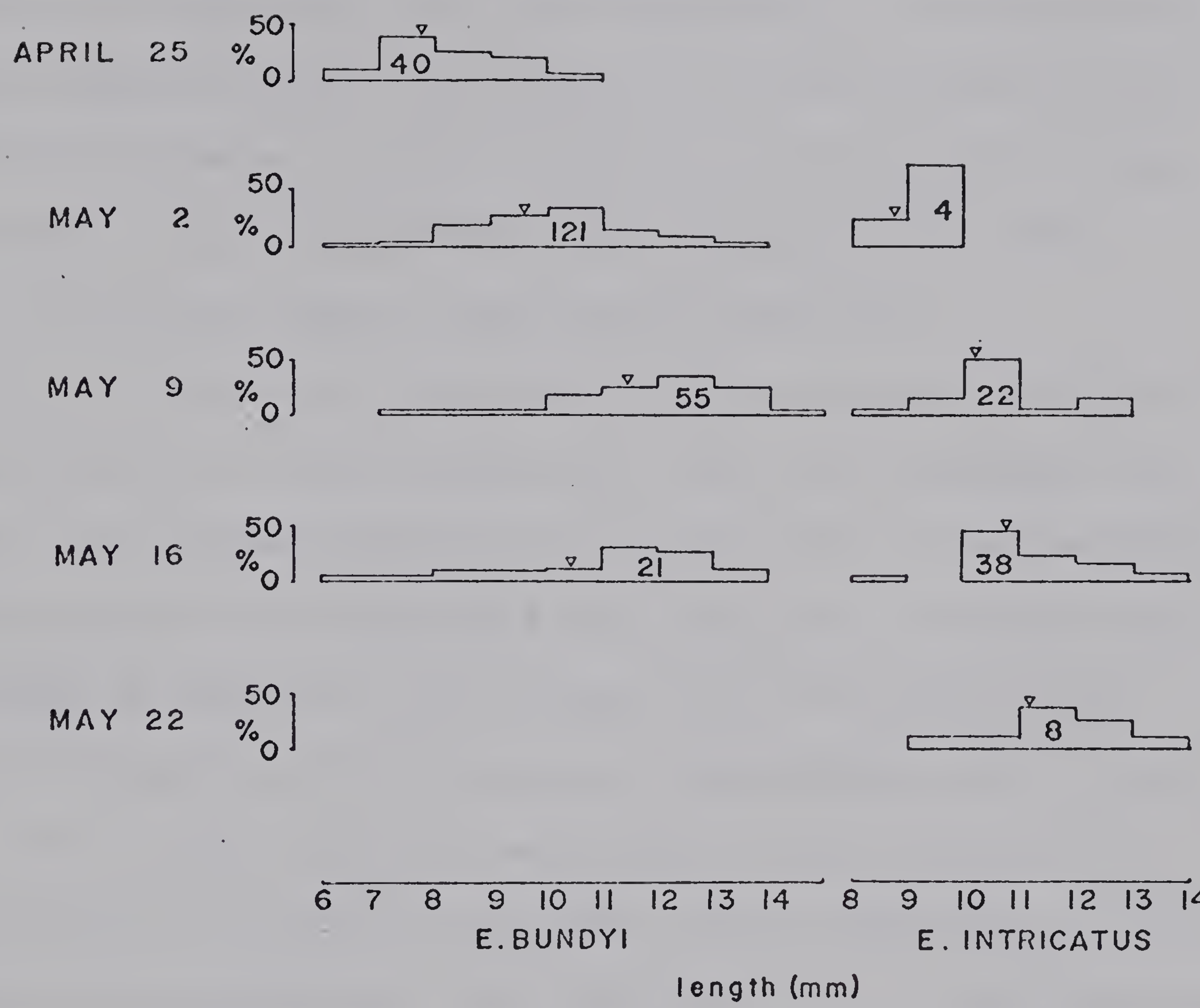

Figure 15. Population length-frequency histogram for *Eubranchipus bundyi* and *E. intricatus* females (station 5) 1973. Arrow indicates mean size.

not distinguish the metanauplii and juvenile forms of *E. bundyi* and these forms in *E. intricatus*, these stages of the two species were combined when calculating growth rates (Figures 16 and 17). There was only a slight difference in size between male and female juveniles at both stations. Unlike some other fairy shrimp (e.g., *Branchinecta* spp.), *E. bundyi* exhibits a linear length-weight relationship (Daborn, 1974). *Eubranchipus* hatches as an advanced metanauplius, there being no free-living naupliar stage. Both Daborn (1974) and Broch (1963, 1965) discuss the pre-adult stages of *Eubranchipus* development.

The mean size of the first *Eubranchipus* metanauplii in 1973 was 0.7 mm (this was on 3 April, at which time only a few metanauplii were observed; it was assumed that this was near the date of first hatching). The sexes were first distinguishable on 25 April, and the species could be recognized as early as 25 April (Figure 14), but because of the extended hatching period of both species, unidentifiable juveniles were present until 10 May. Unlike the adaptation of other branchiopods in Sounding Creek (e.g., *Lynceus mucronatus*), the two *Eubranchipus* species showed no obvious reproductive cycle adaptations (e.g., rapid completion of the naupliar stages) to temporary water environment.

In 1972, *Eubranchipus intricatus* and *E. bundyi* were present at all stations. Metanauplii were initially abundant only at station 1. Adult *E. bundyi* were later recorded from station 1, but they never became abundant. Main concentrations of *Eubranchipus* in 1972 were at stations 5 and 6 (station F was not sampled in 1972).

Adult *Eubranchipus ornatus* were occasionally found in both 1972 and 1973 in very early spring. Table 24 indicates date of occurrence, size and sexual condition of adult *E. ornatus*. *Streptocephalus seali* was

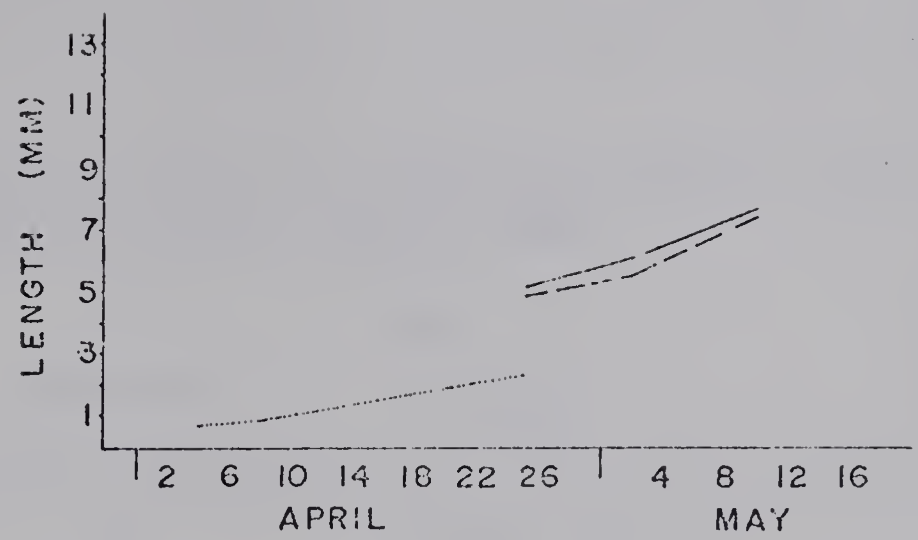

Figure 16. Growth rate of immature *Eubranchipus* at station 5, 1973.

------ males, ______ females, ... sexually indistinguishable

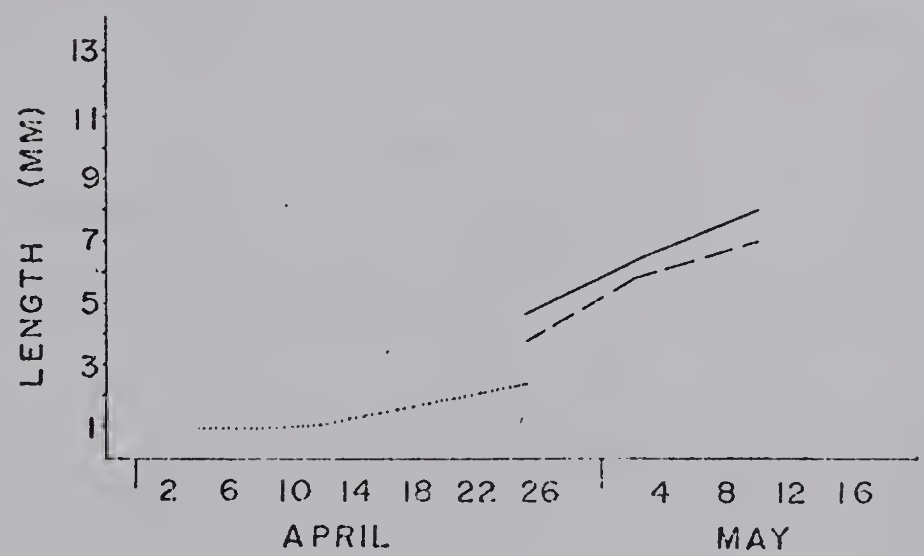

Figure 17. Growth rate of immature *Eubranchipus* at station F, 1973.

----- males ——— females ..... sexually indistinguishable.

Table 24. Occurrence and size of *Eubranchipus ornatus*, 1972 and 1973 (* indicates female carrying eggs)

1972

Date	Station	Male (mm)	Female (mm)
April 19	2	4.0, 5.0	-
		6.5, 7.0	
	2	9.0, 10.0	10.0, 10.0*
			11.0*, 13.0*
	3	11.5, 9.0	-
	4	9.0	9.0*
	5	9.0	10.0*

1973

Date	Station	Male (mm)	Female (mm)
April 25	5	8.0, 9.0	-
	F	8.0, 10.0	7.0, 8.0,
			9.0*
May 2	5	10.0	14.0*

found only once in 1972 (two male and one gravid female--16 June) and not at all in 1973. Mature *Branchinecta paludosa* were found on 25 May 1972 at station 5 and on 9 May 1973 at station F. Other immature *Branchinecta* spp. were found in the spring of both years, shortly after breakup.

Conchostraca

Three species of conchostracans occur in the study area. *Lynceus brachyurus* and *L. mucronatus* are found in large numbers, mainly at stations 5 and F. *Cyzicus mexicanus* was occasionally taken in dip net samples in 1972 and 1973 at most stations.

Metanauplii of both *Lynceus* species were taken in dip net samples as early as 5 April 1973, shortly after the ice had melted. Table 25 indicates the density of the metanauplii taken in plankton samples. Maximum recorded abundance of *L. brachyurus* was 127/liter, while greatest recorded abundance of *L. mucronatus* was 48/liter.

Reproduction. Although both species are superficially similar through all life cycle stages, distinct differences are evident in growth rates and life cycles (Figures 18, 19, 20 and 21). *L. mucronatus* is seemingly more adapted to life in temporary systems, the life cycle being completed in about one-half the time required by *L. brachyurus*. An exponential growth rate for the adults of *L. mucronatus* is evident at both stations. Unlike *L. brachyurus*, which maintained a breeding population well into summer, mature *L. mucronatus* females were found only once after 30 May. Fully formed eggs were first noted in *L. brachyurus* on 13 June, and thereafter almost all females had eggs within the valves. Although *L. mucronatus* was last observed on 30 May (except

Table 25. Density (numbers per liter) of metanauplii of *Lynceus brachyurus* and *Lynceus mucronatus* from plankton samples, 1973

Station 5

Date	*L. brachyurus*	*L. mucronatus*
April 25	128	48
May 2	55	-
May 9	20	-

Station F

Date	*L. brachyurus*	*L. mucronatus*
April 25	81	20
May 2	55	31
May 9	-	7

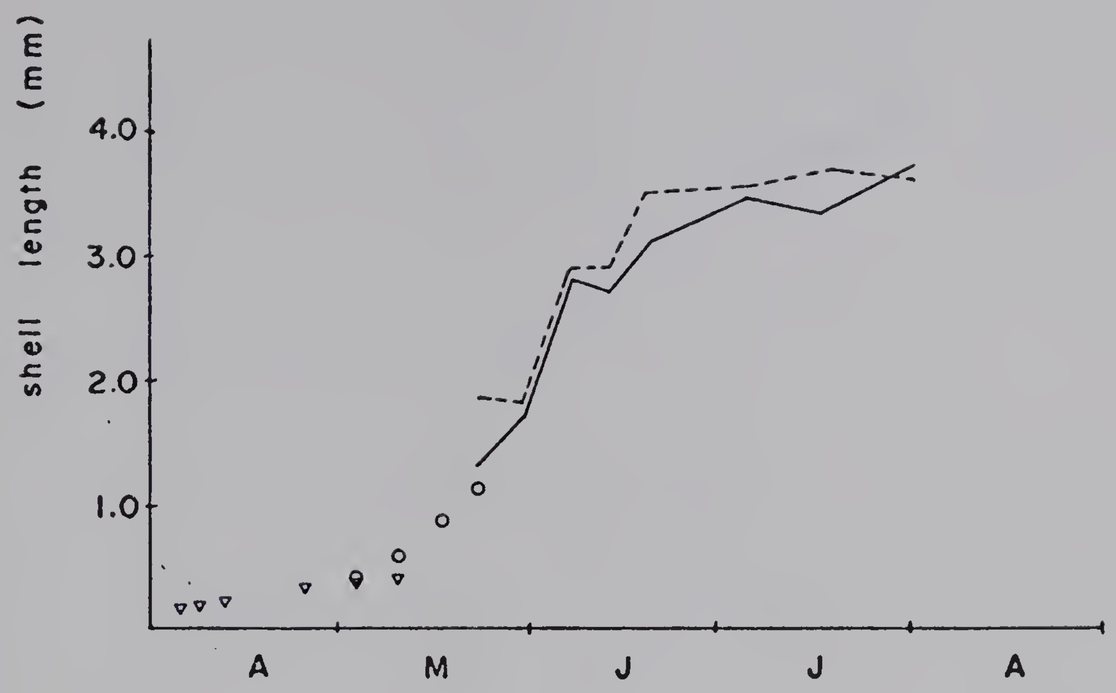

Figure 18. Growth rate of *Lynceus brachyurus* males (solid lines) and females (broken lines) at station F (1973). Juveniles are indicated by open circles. Metanaupliar stages are indicated by triangles.

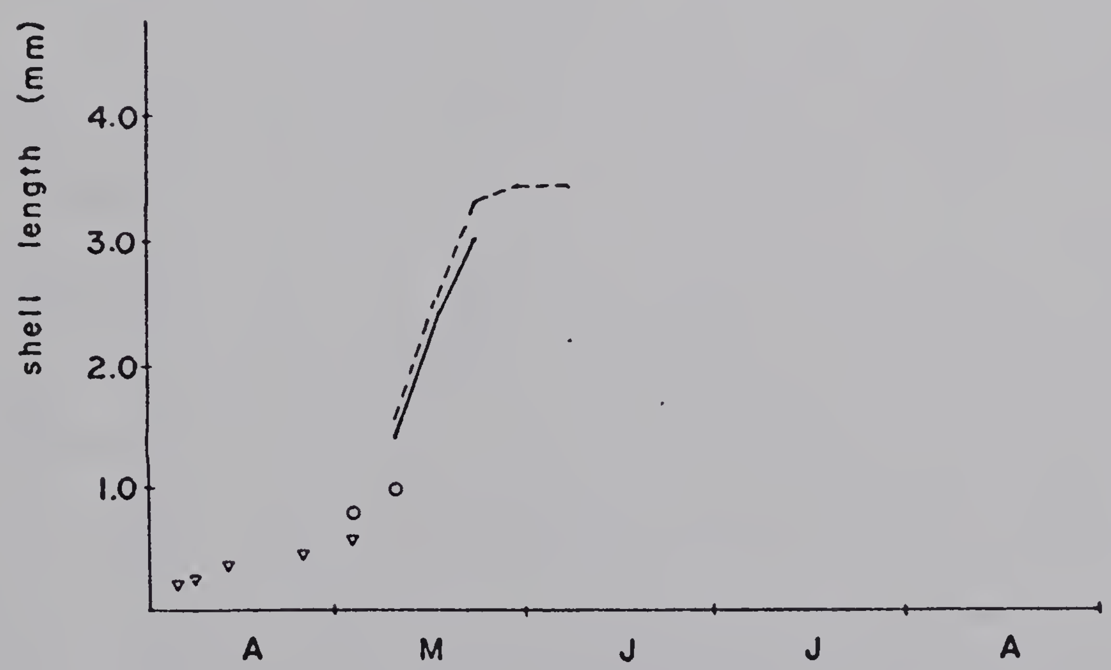

Figure 19. Growth rate of *Lynceus mucronatus* males, females, juveniles and metanauplii at station F (1973). See Figure 18 for the legend.

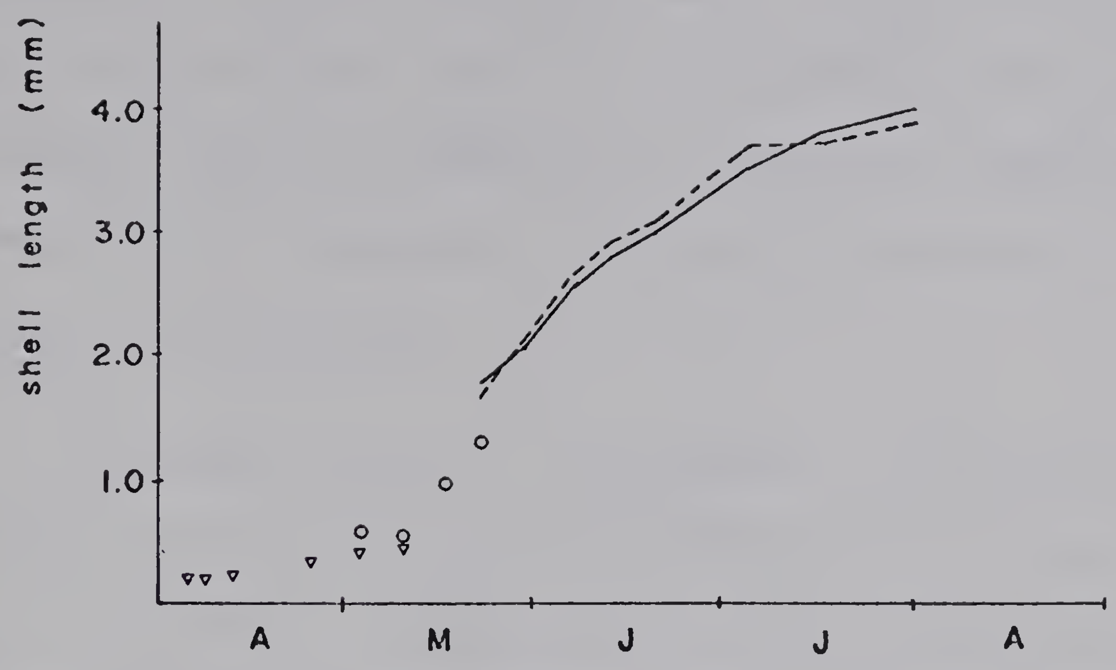

Figure 20. Growth rate of *Lynceus brachyurus* males, females, juveniles and metanauplii at station 5 (1973). See Figure 18 for the legend.

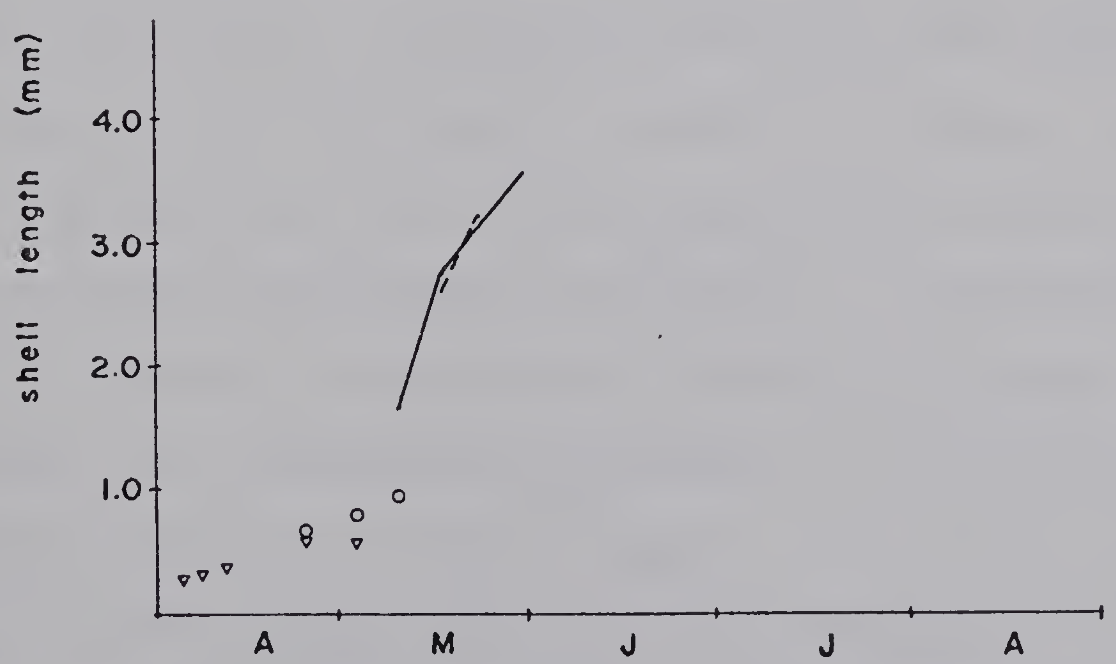

Figure 21. Growth rate of *Lynceus mucronatus* males, females, juveniles and metanauplii at station 5 (1973). See Figure 18 for the legend.

for one specimen taken on 7 June, egg-carrying females were not observed until 22 May. Only two of the 30 females sampled had fully developed eggs within the valves. Most of the eggs were produced between 22 May and 30 May. Figure 22 illustrates the population length-frequency for *L. mucronatus* and *L. brachyurus*, and Figure 23 illustrates the length-frequency of the nauplii.

The Lynceus *nauplius.* Determination of species in immature forms (metanauplius and juvenile) proved difficult in the early stages of the study. The juvenile identification problem was solved when size differences in the two species were determined. Metanaupliar identification proved difficult because Packard (1875), in the original description of *L. mucronatus*, did not describe the immature stages. However, the metanauplius of *L. brachyurus* has been described (Johansen, 1921; Gurney, 1925; and Soloviow, 1927). Comparison of the two species in my samples and analysis of metanauplii and adults from various other locations in Canada has helped to resolve the problem. Figures 24 and 25 are drawings made with a projecting microscope and serve to illustrate the most obvious morphological differences. The metanaupliar rostrum of *L. brachyurus* is bluntly pointed and armed with numerous spinous processes. The rostrum of the metanauplius of *L. mucronatus*, however, is distinctly rounded and devoid of spines. There are also subtle differences in valve spination, but this is not illustrated. I believe my description is the first description of the nauplius of *Lynceus mucronatus* (Packard, 1875).

The third conchostracan present in Sounding Creek is *Cyzicus mexicanus*. This large conchostracan occurred sporadically in 1973 at all stations, but achieved fairly high abundance at times in 1972 ($258/m^2$,

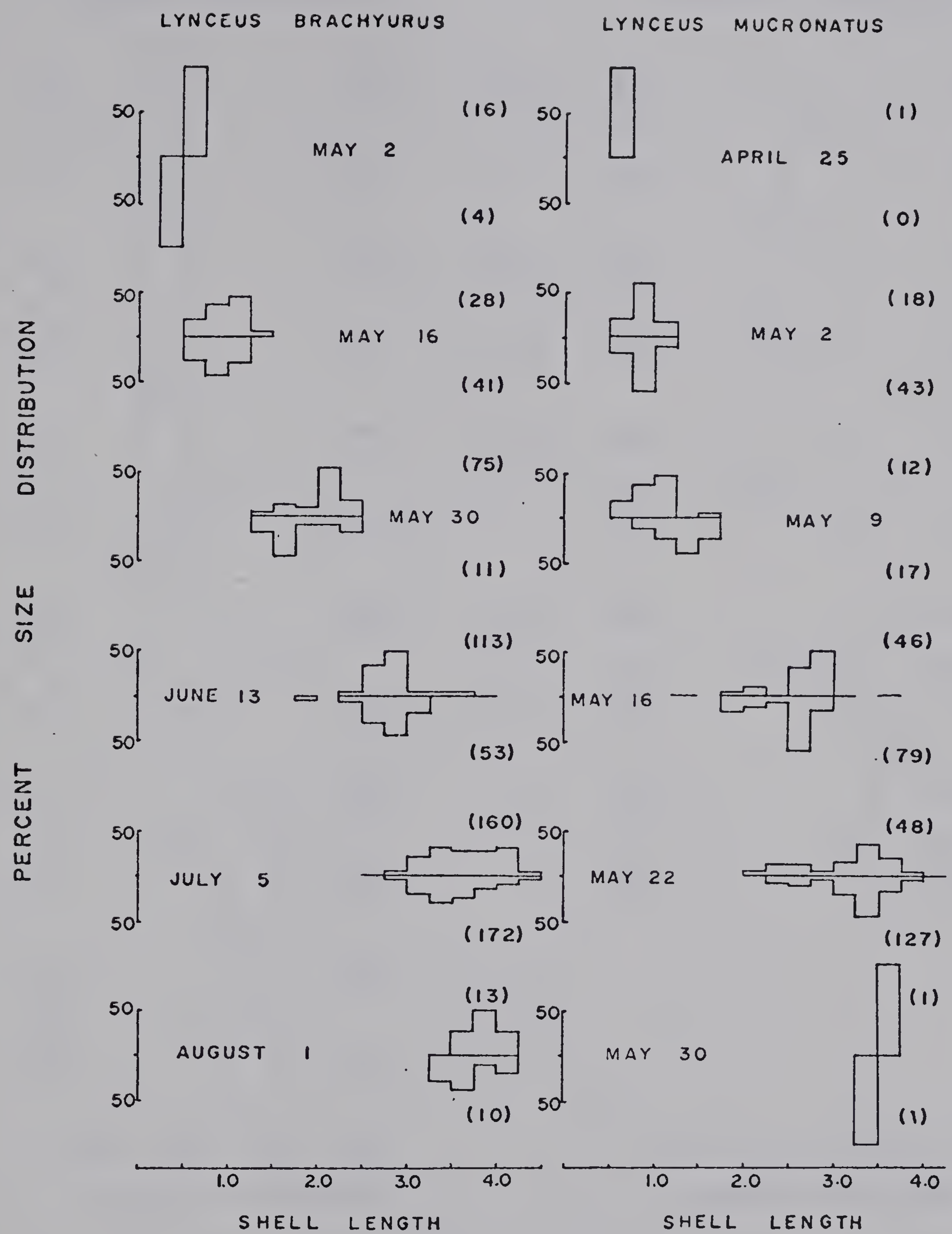

Figure 22. Length-frequency histogram of *Lynceus brachyurus* and *Lynceus mucronatus*, 1973. The upper part of each graph represents station 5 and the lower part, station F. Numbers in brackets are total numbers of animals measured.

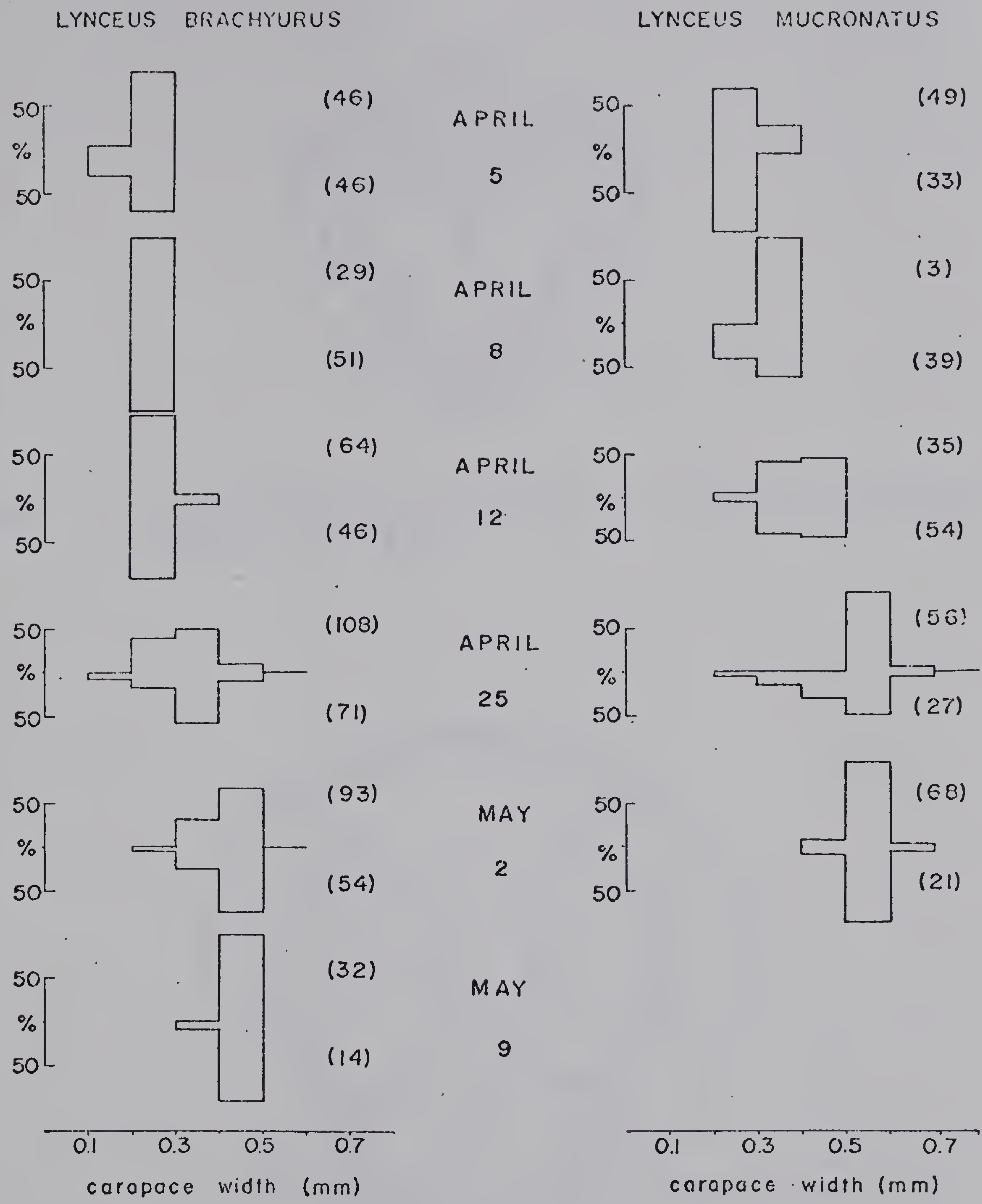

Figure 23. Length-frequency histogram of *Lynceus brachyurus* and *L. mucronatus* metanauplii (stations 5 and F, 1973). Values in brackets indicate numbers of animals (station 5 at top; station F at bottom).

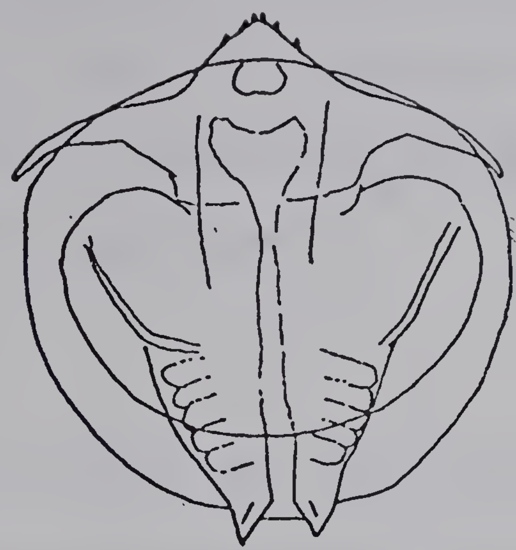

Figure 24. *Lynceus brachyurus* metanauplius, X 206 (shell spination omitted), 2 May 1973

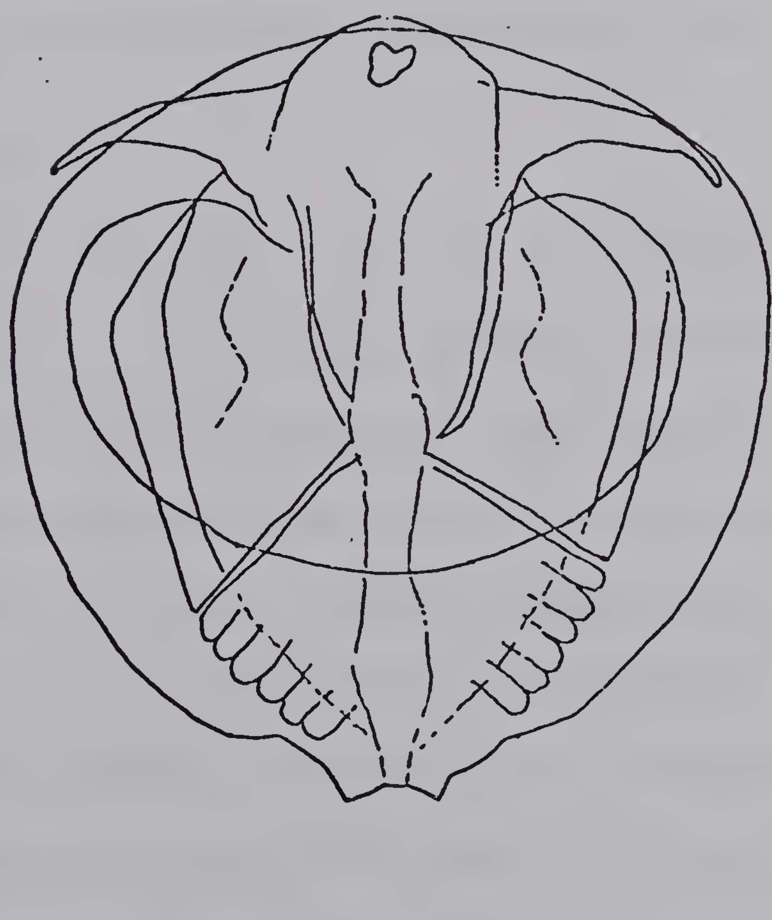

Figure 25. *Lynceus mucronatus* metanauplius, X 206 (shell spination omitted), 2 May 1973

7 July 1972; 172/m^2, 16 June 1972). Maximum recorded size of living individuals was 7.9 mm (16 June 1972), although shells of dead animals were found as large as 16 mm. Nauplii and metanauplii of *C. mexicanus* were frequently observed in early spring.

Notostraca

Although *Lepidurus couesii* was rarely found in dip net samples in 1972 or 1973, numerous dead animals were found each year when the stations dried up. *Lepidurus* occurred mainly at station F and also outside the study area in areas considerably downstream of station 6. Small numbers of juvenile tadpole shrimp were found on 3 May 1973 at stations 3 and 4. Juvenile carapace length ranged from 0.87 to 1.24 mm. Mature carapace length was usually greater than 20 mm.

Ostracoda and Amphipoda

More than nine different ostracods were identified. Figure 26 indicates the occurrence of the major ostracods (1972-1973). In both years, *Cypris pubera* was most abundant. This large ostracod (maximum size about 2.7 mm) appeared in the beginning of May and rapidly grew to mature size by the end of May. Females carrying eggs were first observed on 7 June 1973. *C. pubera* was one of the few ostracods that were present at all stations. *Candona rawsoni* and *Cyclocypris ampla* were found throughout the open water season, but were restricted in their habitats. *C. ampla* was abundant early in the spring and was rarely found outside stations 1 or 2, except after periods of flood. *C. rawsoni* occurred mostly at station 3 and rarely at station 4. *Candona acutula* occurred at about the same time as *C. rawsoni*, but was not as abundant.

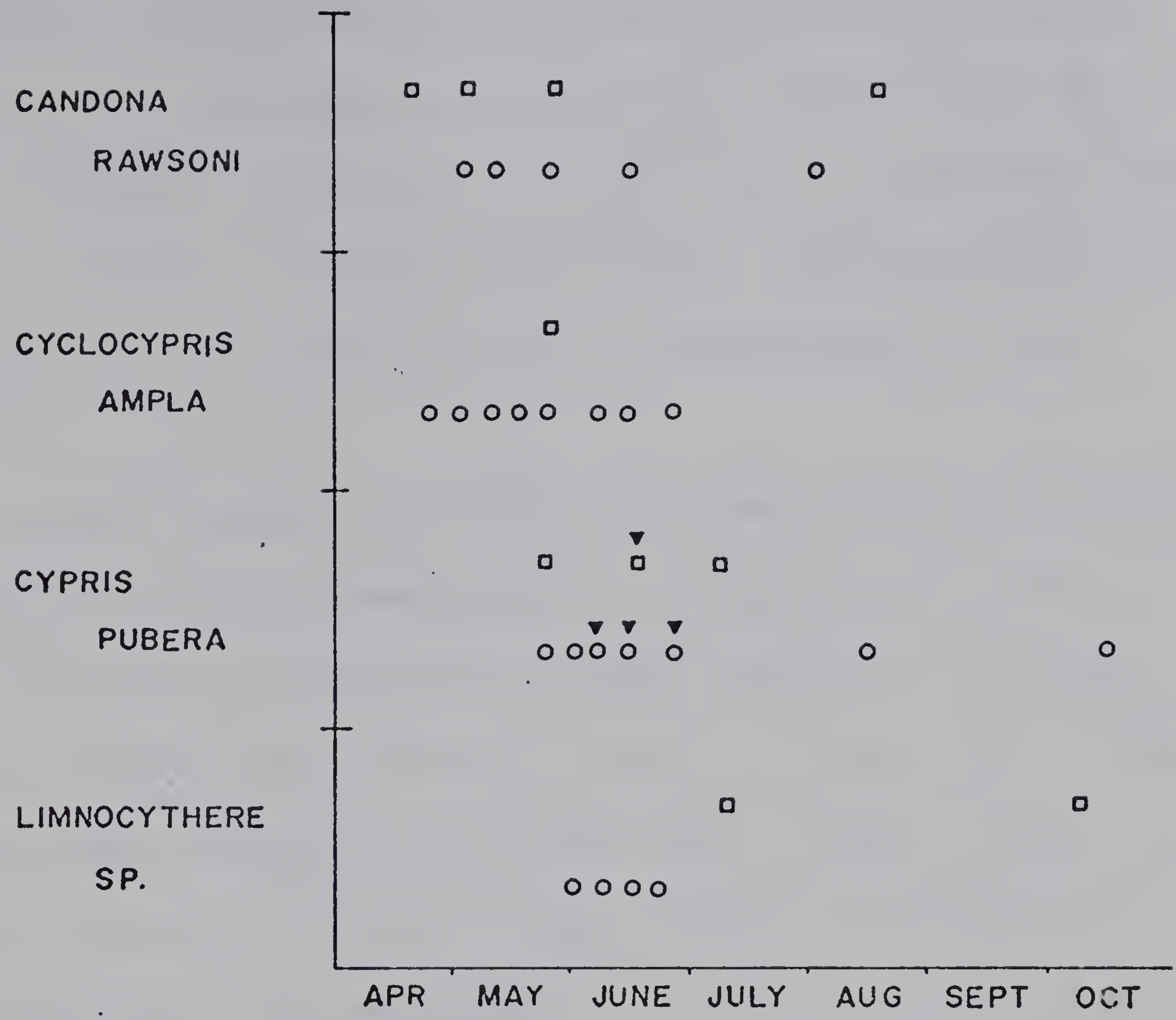

Figure 26. Occurrence of major ostracods in Sounding Creek (1972-1973), all stations combined

□ 1972

○ 1972

▼ eggs present

Cyclocypris sharpei (occurring in early April) and *Cypridopsis vidua* (maturing about mid-June) were rarely found. *Limnocythere* was present sporadically at stations 4, 5, 6 and F near the beginning (1973) and near the end (1972) of the open water season. *Cypricercus horridus* was found only rarely at stations 5 and F in the beginning of each spring.

Two species of amphipod, *Hyallela azteca* and *Gammarus lacustris*, were present in the Sounding Creek system. *G. lacustris* was present at all stations throughout the year, but was most abundant in stations 1 and 5. Pairs in copula were observed as early as 12 April 1973; females with eggs were first observed in the latter part of April. Young *Gammarus* first appeared at the end of May. *Gammarus* possibly over-wintered by burrowing in the bottom mud.

Hyallela, unlike *Gammarus* which appeared immediately after break-up, did not become abundant until the beginning of May. Before the flood, *H. azteca* was only abundant at station 1 and rarely was found at the temporary stations (5 and F). However, the flood of 1973 served to disperse the amphipods throughout the study area. Females began to carry eggs in mid-May, but free-swimming young *Hyallela* were not found until mid-June. *H. azteca* reproduced throughout the remainder of the open water season. Only small *H. azteca* were found at the end of the field season, and it is presumed that these overwinter by burrowing into the bottom mud. *Hyallela* possibly overwinters frozen in the ice (Daborn, 1969).

Ephemeroptera

During the general survey of 1971, large numbers of *Caenis* sp. were found. Although no adults were collected, last-instar nymphs were present in late summer. In 1972 and 1973, four species of mayflies were collected (Figure 27). *Caenis* was found at only one time in each year and *Centroptilum* occurred in only one sample in 1973. *Paraleptophlebia praepedita* seemed to have only one generation per year. Small *P. praepedita* nymphs (2-3 mm) were found near the end of May, and large nymphs (but not last-instar nymphs) were found in mid-June. No adults were collected. In 1973, large numbers of *Callibaetis pallidus* occurred in a marshy area about 100 m north of my study area. *C. pallidus* was abundant in 1972 at all Sounding Creek stations but occurred much less frequently in 1973. Late-instar nymphs were found from mid-May to early June and from July to August, indicating two generations per year. Subimagos were collected in late May and mid-August.

Odonata

Five species of Zygoptera (*Lestes* and *Enallagma*) were found in the Sounding Creek system. Four species of *Lestes*: *L. congener*, *L. disjunctus*, *L. dryas* and *L. unguiculatus* were identified from adults and late-stage nymphs. Table 26 indicates the total number of *Lestes* present at selected stations on each sample date. Emergence data for *Lestes* and *Enallagma* are summarized in Table 27. Generally, the damselflies emerged in July and August. All species of *Lestes* appear to be univoltine whereas *Enallagma boreale* apparently is bivoltine.

Only one anisopteran was found in Sounding Creek (Table 28). *Tarnetrum corruptum* first occurred in early April (size about 1 mm),

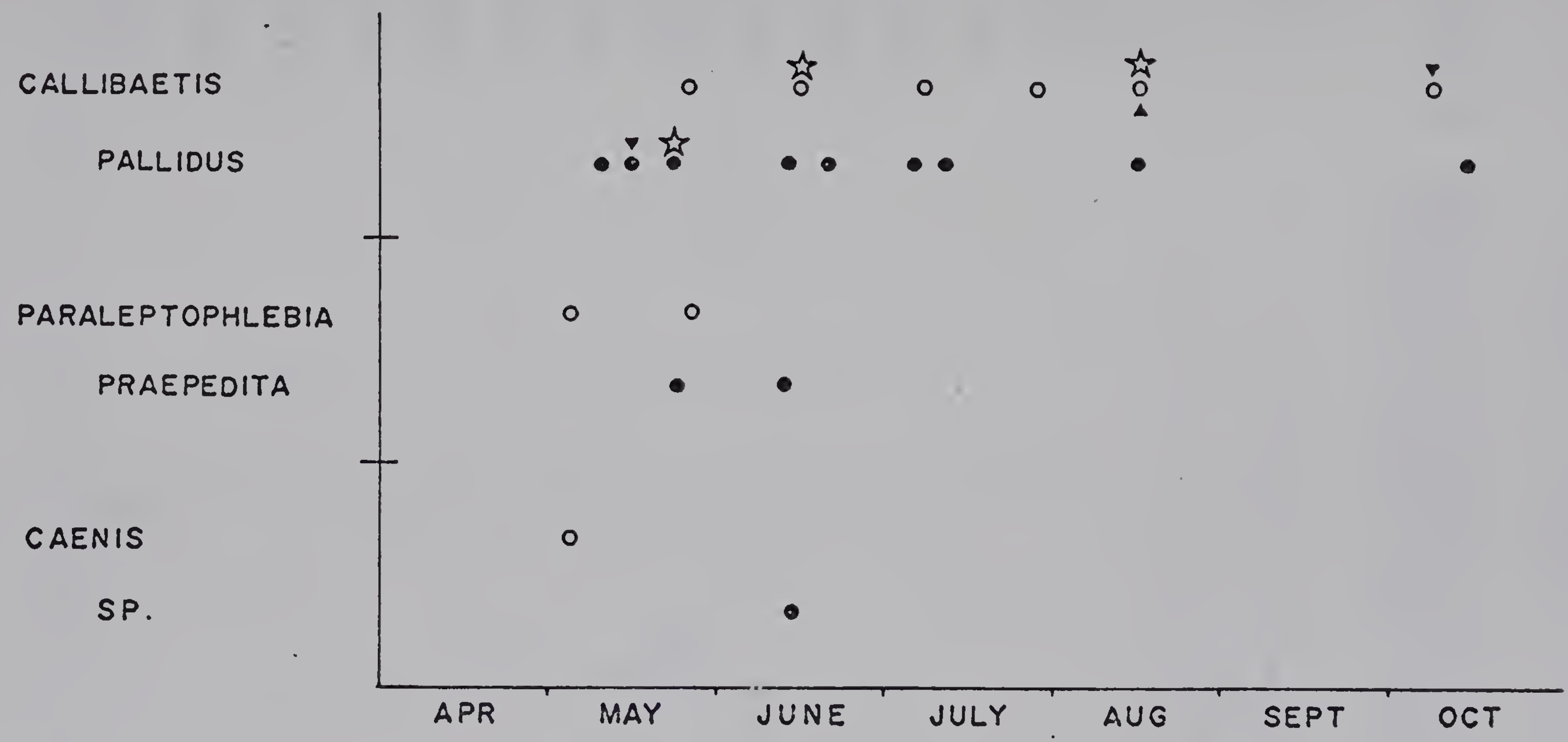

Figure 27. Occurrence of mayflies at Sounding Creek (1972-1973), all stations combined

○ 1972 nymphs ☆ adults

● 1973 nymphs ▼ last-instar nymphs

Table 26. Numbers of *Lestes* spp. collected (qualitative sample) from selected Sounding Creek stations, 1973

Date	Station 1	Station 6	Station 5	Station F
04/12	-	-	1	-
04/25	-	-	2	2
05/02	-	-	4	84
05/09	-	-	3	4
05/16	1	-	61	15
05/22	25	7	135	27
05/30	30	109	64	29
06/07	9	38	50	17
06/13	7	22	37	18
06/20	-	2	32	48
07/05	4	5	10	10
07/17	3	3	5	16
08/01	-	-	3	2
08/15	-	-	-	-

Table 27. Date of emergence of the five species of damselflies in Sounding Creek, 1972 and 1973

(○ - 1972 ● - 1973) (P● - mature nymph)

SPECIES	MAY	JUNE	JULY	AUGUST
ENALLAGMA BOREALE	P●	○	●	
LESTES CONGENER			○	● ○ ●
LESTES DISJUNCTUS			○	● ○ ●
LESTES DRYAS		○	●	●
LESTES UNGUICULATUS			●	

Table 28. Number of *Tarnetrum* collected at each station (1972 and 1973). * indicates adults were collected.

Date	Station						
	1	2	3	4	5	6	F
04/19/72	-	-	8	11	8	6	
05/03/72	-	-	5	3	8	3	
05/25/72	3	-	11	77	10	65	
06/16/72	-	1	-	-	2	6	
08/16/72*	-	-	-	-	-	-	
04/08/73	-	-	-	-	-	-	1
04/12/73	-	-	-	-	-	-	1
05/02/73	-	-	-	-	-	-	1
05/16/73	-	-	-	-	-	-	35
05/22/73	-	-	-	-	5	-	91
05/30/73	-	-	-	-	14	-	65
06/07/73	-	-	-	-	4	-	21
06/13/73	-	-	-	-	13	1	9
06/20/73	-	-	-	-	55	-	63
07/05/73	-	-	-	-	10	-	10
07/17/73*	-	-	-	1	1	-	1
08/01/73*	-	-	-	-	1	-	2
08/15/73*	-	-	-	-	-	-	1

shortly after the ice broke up. Only one generation was evident in both years, although considerable size overlap indicated hatching over an extended period. Emergence in both years occurred in late July and early August. The young evidently overwintered in the egg stage.

As is evident with *Lestes* spp., *Tarnetrum* showed a distinct preference for stations 5 and F and, later in the summer, 4 and 6 as well (1973). In 1972 both genera were much more evenly distributed although a preference for 5 was still evident (station F was not sampled in 1972). This is apparently a result of the growth of aquatic macrophytes at stations 5 and F, particularly in 1973.

Hemiptera

Thirteen species of corixids were found in Sounding Creek (Appendix 1). The most commonly occurring corixids were *Callicorixa audeni*, *Trichocorixa borealis* and *Sigara* spp. All other species occurred infrequently, being common in samples during the corixids' migration periods (Figure 28). Only one species of gerrid, *Gerris buenoi*, was identified from Sounding Creek and was present throughout the free-water period. A few *Notonecta kirki* and *N. undulata* were found and, very rarely, saldid bugs (*Saldula pallipes*) were collected.

Trichoptera

Limnephilus sp. and *Agrypnia pagatina*, the most abundant caddis flies, occurred at all stations (Figure 29). Larvae of *Agrypnia* appeared in early April and were last seen as pupae in early June. Adult *Agrypnia* were found in late May 1972 and from mid-May to mid-June 1973. Small *Limnephilus* were present shortly after ice breakup (5 April

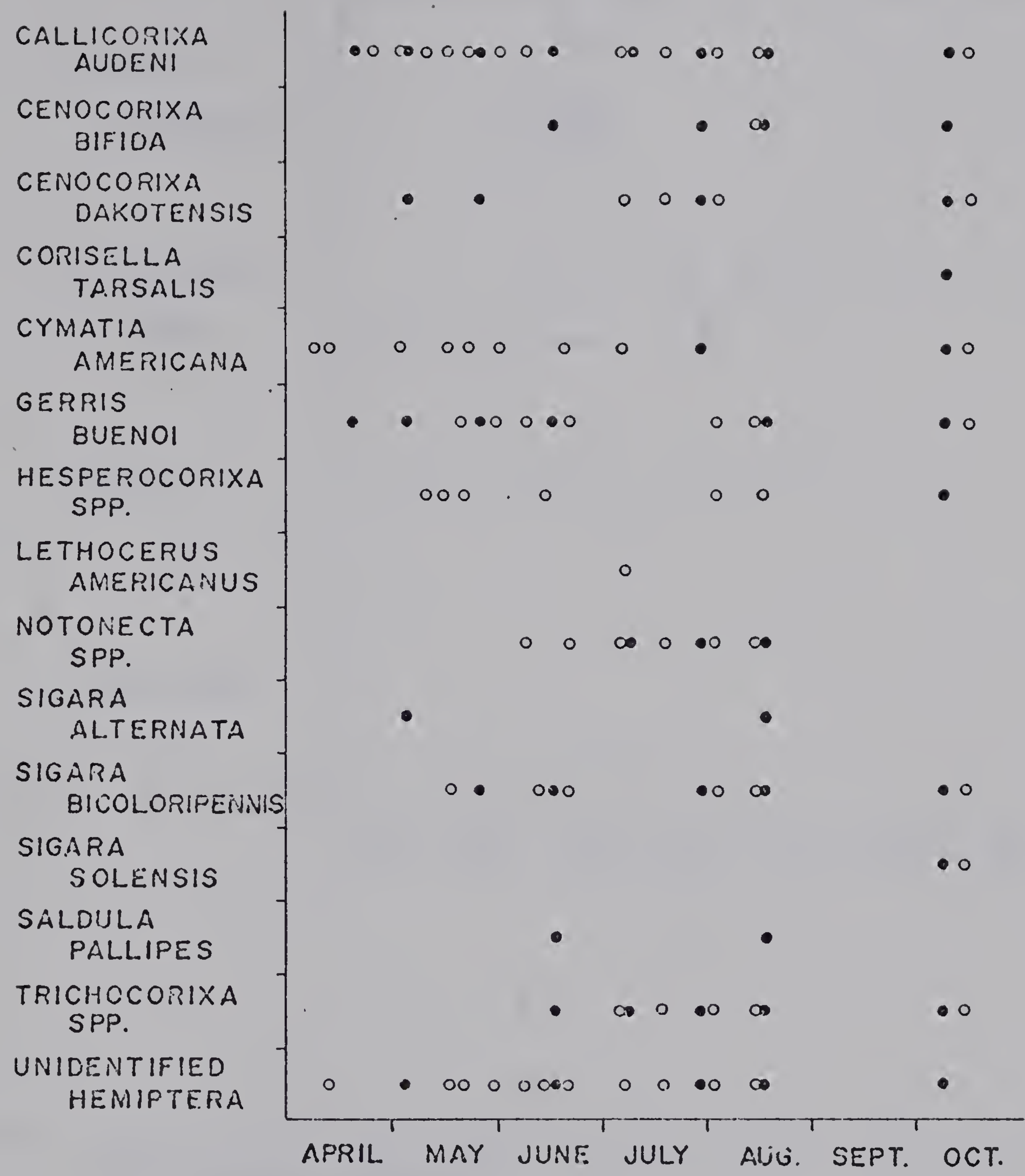

Figure 28. Occurrence of Hemiptera in Sounding Creek waters, 1972 and 1973

● - occurrence 1972 ○ - occurrence 1973

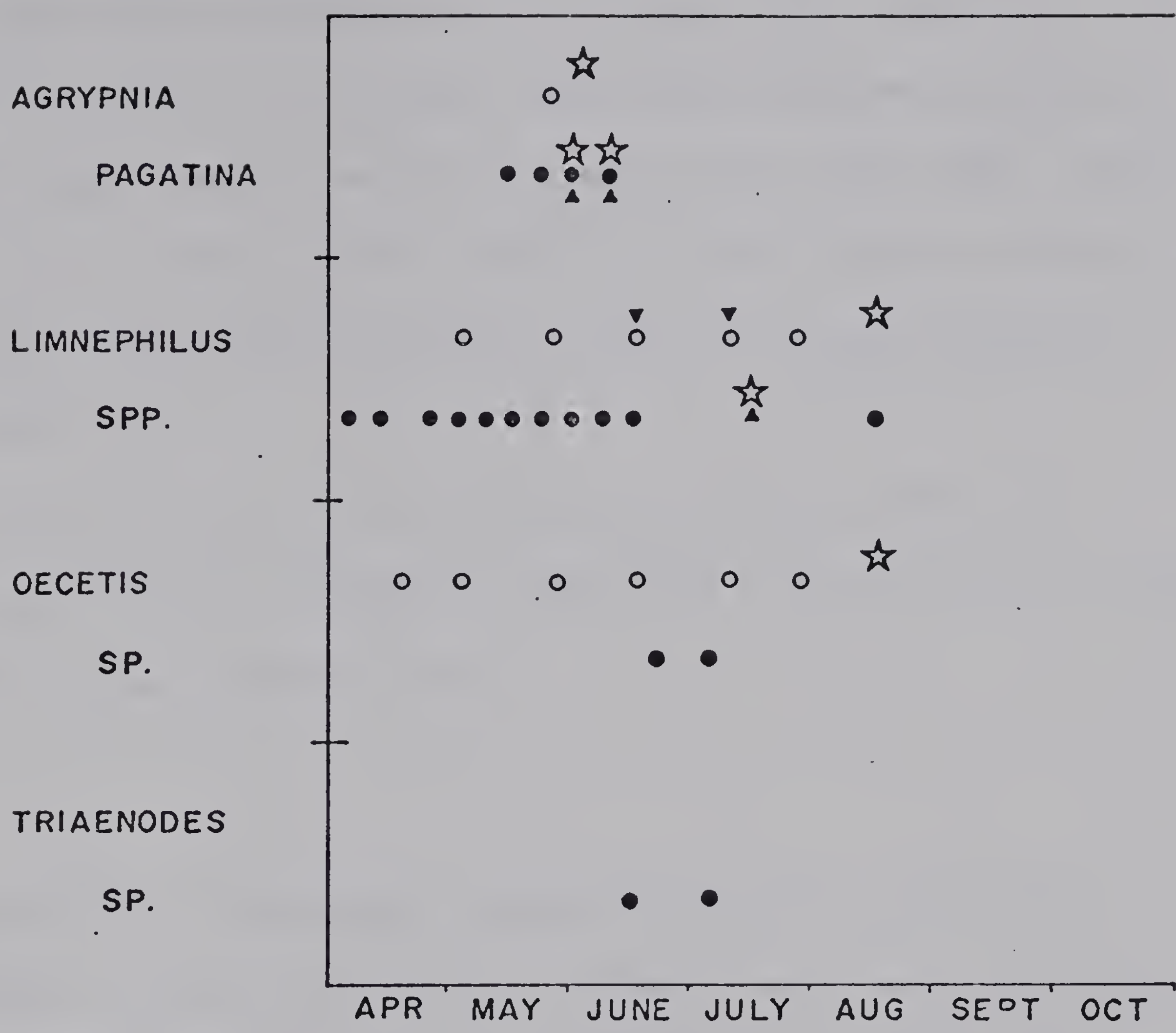

Figure 29. Occurrence of Trichoptera at Sounding Creek, 1972 and 1973 (all stations combined)

○ 1972 larvae ☆ adult

● 1973 larvae ▼ pupae

1973) and occurred as larvae until mid-July at which time pupae were collected. Pupae were last observed on 15 August 1973. This is considerably later than in 1972, when pupae were collected as early as mid-June. Only empty pupal cases were found in late July 1972. *Oecetis* larvae were found in many samples in 1972, but their numbers remained low. *Oecetis* and *Triaenodes* were rare in 1973 and mostly occurred after the flood.

The flood of June 1973 drastically affected the caddis fly population, particularly at station F (Table 29) where an apparent influx of caddis flies caused elevated values.

Diptera

Eight families of dipterans occurred in Sounding Creek and, although a large diversity was evident, dipterans were only occasionally abundant. The Chironomidae were present throughout the year, but usually in small numbers. A peak of abundance of *Corynoneura* sp. occurred in the spring of 1973. These chironomids were also found in large numbers in shallow pools of astatic water in the Sounding Creek basin. Most chironomids were Chironominae (mainly *Glyptotendipes* and *Cryptochironomus*) and occurred in greatest numbers before the mid-June flood (rarely more than 10% of the animals by number).

The Chironomidae were the most important animals in the bottom fauna in Sounding Creek and were the major group contributing to the bottom biomass. Figure 30 shows the relationship of relative abundance of the various taxa of animals present in the benthos. Bottom fauna animals, other than chironomids, were rarely encountered. One exception was *Cyzicus mexicanus* in June and July. Infrequently found in standard

Table 29. Effect of flood (20 June 1973) on the trichopteran fauna. Numbers are total Trichoptera collected at each station with a dip net.

Date	Station					
	1	3	4	6	5	F
June 7	5	0	3	3	12	14
June 13	2	1	6	1	19	2
June 20	1	0	1	0	5	169
July 5	5	0	1	0	36	9
July 17	6	0	8	0	2	3

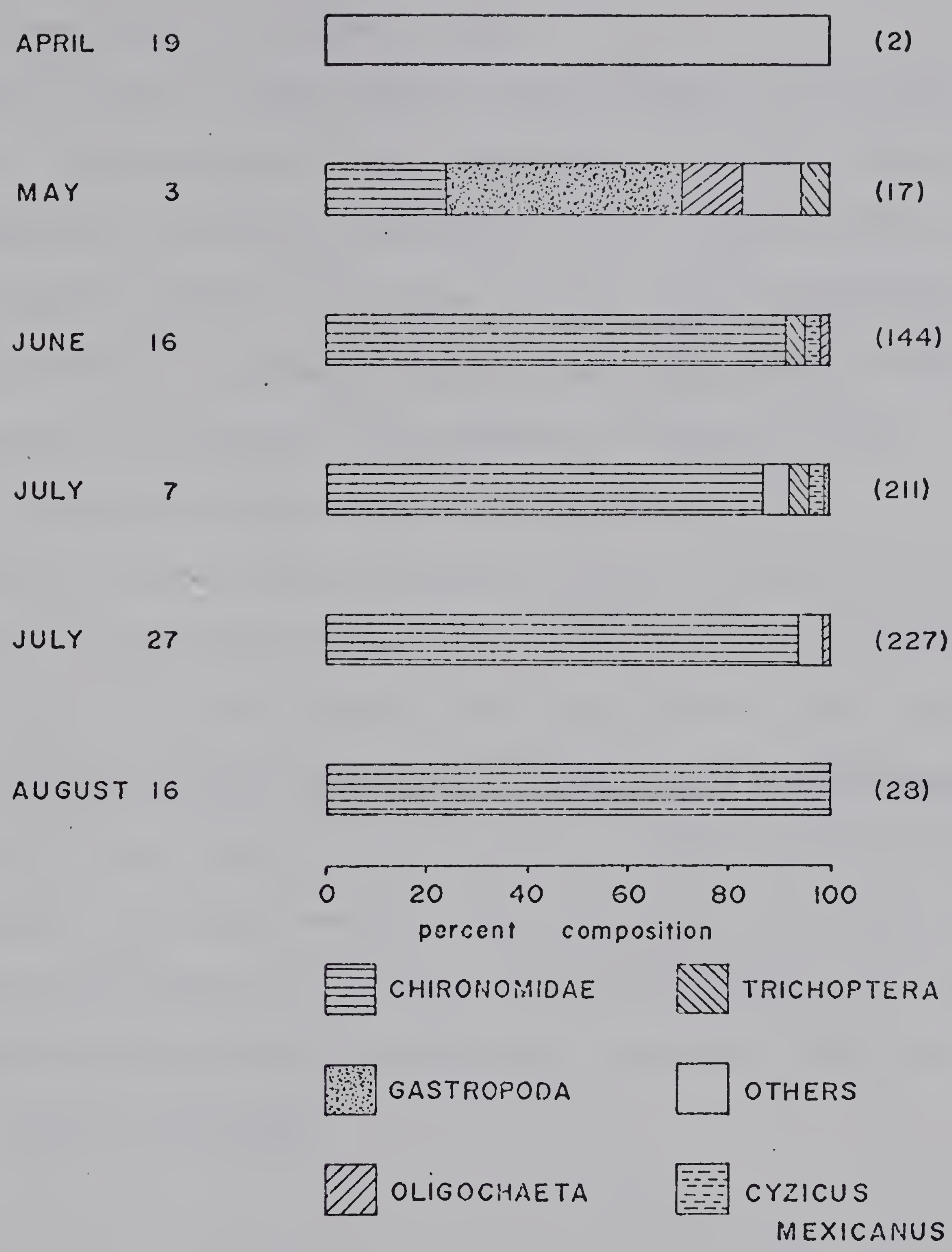

Figure 30. Percent composition of animals in bottom samples from Sounding Creek, 1972 (numbers in brackets are total animals per sample using a 6-inch (15.24 cm) Ekman dredge)

dip net samples, this conchostracan was a surprising find in the permanent water below the highway bridge.

Aedes sp. was the most common culicid present in both years (Figure 31). Two population peaks, early spring and fall, occurred in 1972. Unlike 1972, *Aedes* only occurred in early spring of 1973 and was the only mosquito present at that time. A few *Chaoborus americanus* larvae were found in the summer of 1972 (Figure 31). Pupae occurred from about late July to mid-August. Few *Chaoborus* occurred in 1973. *Mochlonyx* sp. occurred only once, in early spring of 1972.

Perhaps the most distinct seasonal abundance cycle was exhibited by black flies (Simuliidae) (Figure 31). Small larvae (tentatively identified by M. Chance as *Cnephia*) were found in both moving and still habitats in early spring of both years. These larvae had disappeared by early May of both years. On 20 June 1973, no black flies were present in the system. By 5 July, however, larvae and pupae of *Simulium vittatum* covered the bottom substrate and vegetation of station 3. On 1 August, only a few larvae persisted. No adults were collected. The source of the black flies is not known.

Mollusca

Mozley (1938) found only *Lymnaea elodes* and *L. caperata* in intermittent streams in the Quill Lakes Basin of central Saskatchewan. Although *L. elodes* and *L. caperata* were among the abundant snails of Sounding Creek, five other gastropods occurred (Appendix 1). *Gyraulus deflectus*, *Promenetus umbilicatellus*, *Lymnaea reflexa* and *L. stagnalis* were only occasionally found in dip-net samples, but *Physa gyrina* was always abundant. A single pelecypod, *Pisidium* cf. *ferrugineum*, was

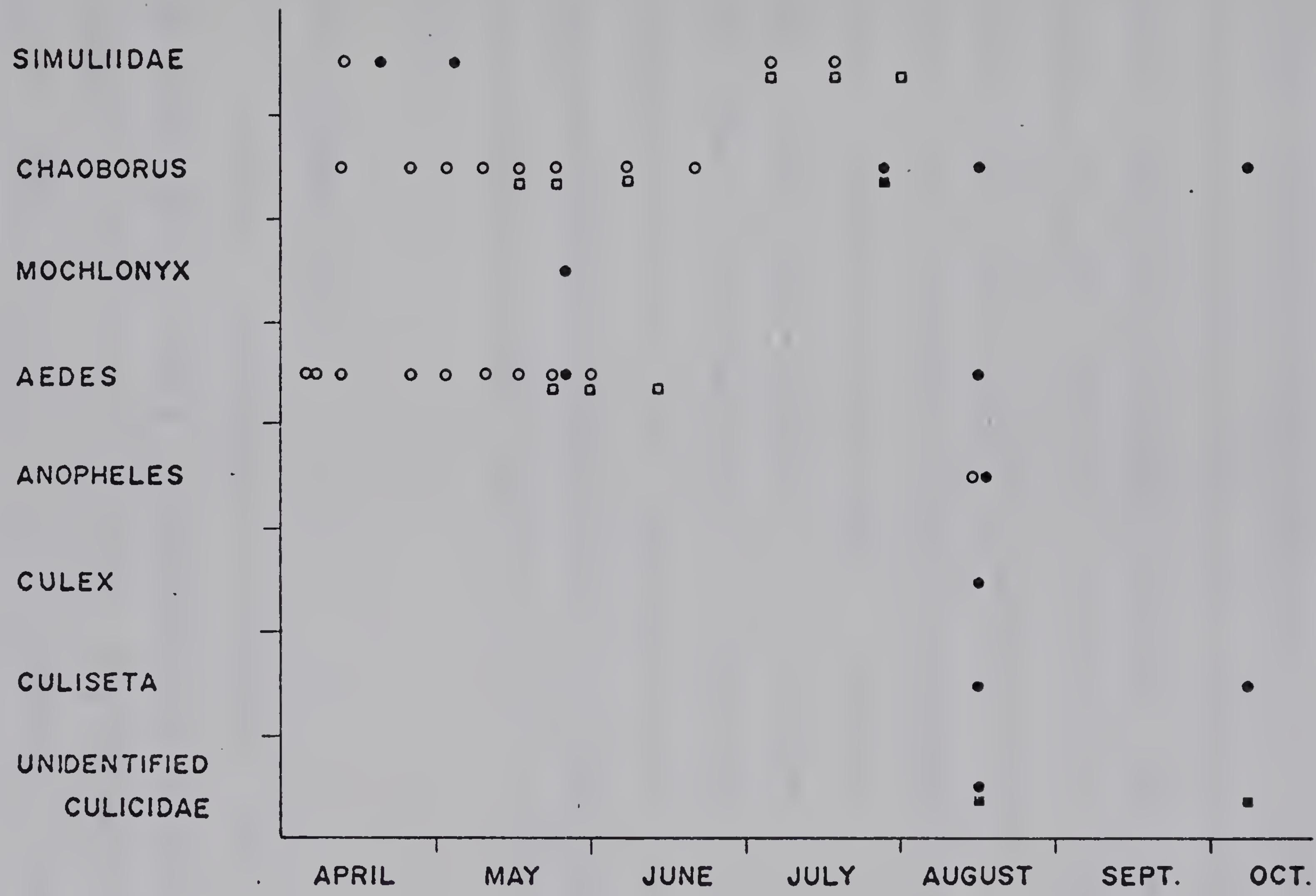

Figure 31. Occurrence of Simuliidae and Culicidae in Sounding Creek waters, 1972 and 1973

● 1972 larvae ○ 1973 larvae

■ 1972 pupae □ 1973 pupae

collected.

The three abundant gastropods (*L. elodes*, *L. caperata*, *P. gyrina*) usually constituted more than 90% of the total molluscan fauna. Gastropods were present for the entire open water season and seemed to maintain reproduction throughout the year. The presence of many large specimens of *Lymnaea elodes* (up to 12 mm) shortly after ice breakup indicated that they overwintered in the adult form. Mozley (1932) observed that *L. palustris* secreted a diaphragm across its shell aperture, and in this way was able to aestivate on the bottom of dried ponds for more than 10 months. It is not known if the other snails use this method of withstanding dry or frozen periods, but dry bottom samples revealed viable adults of *L. caperata*, *P. gyrina* and *P. umbilicatellus*. Laboratory experiments indicated that *L. elodes*, which had secreted a diaphragm and were lying dormant, were able to reactivate within 5 to 10 minutes.

Miscellaneous Groups

Although a great variety of Coleoptera were present throughout the sample period, only a few species, such as *Rhantus* spp. and *Laccophilus biguttatus*, were present in relatively large numbers as larvae. Refer to Appendix 1 for full listing of beetles found in Sounding Creek.

Several taxa of invertebrates were rare in Sounding Creek. Only one tardigrade was collected. Nematodes occurred in surprisingly low numbers. Two bryozoans, *Plumatella repens* and *Fredericella sultana*, occurred in very low numbers; in contrast, bryozoan statoblasts were quite common. *Hydra* sp. occurred in low numbers in both years. In

1972, sexually reproducing animals were observed on 16 August, but in 1973 only asexual budding was observed. There was a large number of water mites (Hydracarina) at all stations, and their immature stages were frequently found as ectoparasites on a variety of other invertebrates, especially Hemiptera and Trichoptera. The most common platyhelminth was a large, predaceous rhabdocoel, *Mesostoma ehrenbergi*. This species plus an unidentified smaller rhabdocoel were most abundant during the spring months. Resting eggs were noted within rhabdocoel bodies in late summer.

Vertebrates

Reptiles. *Thamnophis radix* (plains garter snake) was occasionally seen within the study area boundaries; they apparently were hunting frogs and salamanders in the stream proper.

Amphibia. Three species of frogs, *Rana pipiens*, *R. sylvatica* and *Bufo hemiophrys*, were collected. Only *B. hemiophrys* was abundant. Elaborate courting displays of this species were observed in May of 1973. Larvae of *Ambystoma tigrinum* were occasionally collected, but in small numbers. The tiger salamander is not a normal temporary pond inhabitant (Mozley, 1932). Numerous dead specimens and a few live *Ambystoma* were observed in the large borrow pit west of the study area. Analysis of gut samples of *Ambystoma* from Sounding Creek indicated that *Lestes*, chironomids and *Daphnia* contributed to their diets.

Aves. Only three species of water birds were confirmed to have nested within the study area: sora rail (*Porzana carolina*), American widgeon (*Mareca americana*) and mallard (*Anas platyrhynchus*). Numerous

other waterfowl, e.g., shoveler (*Spatula clypeata*), horned grebe (*Podiceps auritus*), coot (*Fulica americana*), blue-winged teal (*Anas discors*) and pintail (*Anas acuta*), frequented Sounding Creek as a feeding site. A great variety of waterfowl and shore birds utilized the site during spring and fall migrations.

Mammalia. The muskrat (*Ondatra zibethicus*) and beaver (*Castor canadensis*) were quite common in the Sounding Creek valley. A muskrat house was located near the rail bridge and beaver dams (as has already been described) were all too evident. Mink were seen on occasion and were observed feeding on frogs and nesting duck populations.

Pisces. The large, permanent saline lakes of the prairie provinces can have a rich fish fauna, e.g., northern pike, walleye, yellow perch and whitefish (Rawson and Moore, 1944). However, the only fish occurring in Sounding Creek were brook stickleback (*Culaea inconstans*) and fathead minnows (*Pimephales promelas*). Sticklebacks were not collected in 1972 but were abundant in 1973. Before the flood, they were mostly confined to stations 1, 3, 4 and 6. After the flood, stations 5 and F also contained many sticklebacks. Fathead minnows were abundant in both years and present at all stations. What seemed to be an upstream migration of this species was noted on 2 May 1973. No sexually mature fish were observed during this migration, although immature *Pimephales* (0.4 to 0.6 cm) were found from 7 June until the beginning of August. Sexually mature male and egg-bearing female *P. promelas* were only collected on 16 June 1971. McMillan (1973) found *Pimephales* in Saskatchewan breeding from early June until early August.

No *Pimephales* were collected in Sounding Creek after 15 August 1973, but in 1972 they were present as late as October.

DISCUSSION

Although unidirectional flow is the prevalent characteristic of most streams, some streams such as temporary, or astatic, water bodies are devoid of current for much of the year. Most of the moisture content of temporary habitats is supplied via springtime snow melt. Because there is little or no yearly input of water into most temporary streams (except for some ground water recharge and water from occasional rainfall) a considerable reduction in water volume can be observed during the free-water season, and in some cases the stream might go dry.

The generally predictable changes taking place in temporary water habitats are in many respects similar to the predictable aging process of lakes (oligotrophic to eutrophic), although, of course, over a much shorter time scale. The faunal changes taking place during a typical annual cycle in astatic water, such as Sounding Creek, indicate adaptation to the various changing physico-chemical and biological parameters.

Animal communities of temporary waters are faced with a two-fold problem: (1) changes in the physical and biological nature of the aquatic habitat, and (2) changes in salinity and related water chemistry.

PHYSICAL AND BIOLOGICAL CHANGES

Typically, temporary water systems contain free water for only a few months of the year (the definition of types of temporary water has been previously discussed). The seasonal cycle of astatic pools can be

divided into four stages (Kenk, 1949):

1. Autumn-winter stage, characterized by low water temperatures and high oxygen concentration. This stage does not seem to be evident in Sounding Creek.
2. Spring-early summer stage. After an initial influx of spring melt-water, water temperatures rapidly rise and oxygen concentrations gradually decrease.
3. Drying phase, usually lasting about 1 week in late summer. This stage, preceding desiccation, is characterized by high temperatures and very low oxygen concentrations.
4. Dry phase, characterized by a total lack of free water.

Characterization of Astatic Animals

Temporary water inhabitants fall into three major categories: species that apparently prefer temporary habitats and in some cases require astatic conditions, species capable of colonizing both temporary and permanent water bodies, and species that cannot complete their life cycles in astatic conditions.

The initial springtime populations in temporary habitats (e.g., at the more temporary stations of Sounding Creek, stations 5 and F) are dominated by branchiopods (Anostraca and Conchostraca), which, together with other filter feeding organisms, presumably exploit the large amount of bacteria present in the early stages of seasonal succession. Shortly after the temporary body has filled and plant life has begun to flourish, a variety of herbivores and carnivores appear. The amphipods, pulmonate snails (*Gyraulus* and *Physa*), leeches, oligochaetes, dytiscids, chironomids,

etc. may aestivate in the bottom soil once the system dries out, but most cannot survive complete desiccation. A variety of animals (probably those most adapted to live in temporary habitats) produce desiccation-resistant eggs. In Sounding Creek these animals include anostracans, conchostracans, cladocerans, turbellarians and some Trichoptera (Wiggins, 1974). Some animals (e.g., *Agabus*) aestivate in damp soil but are also capable of producing resistant eggs.

Many animals (cladocerans, ostracods, several insects and other crustaceans) inhabit both permanent and temporary habitats. Many permanent bodies of water (e.g., the numerous pothole "sloughs" of western Canada) freeze solid, thereby resembling conditions in temporary habitats; animals inhabiting these habitats require overwintering mechanisms of much the same kind as required by animals in summer-dry phase habitats. Other animals (e.g., Cladocera) normally produce resistant eggs and flourish in both habitat types. Insects normally inhabiting permanent waters can also invade temporary habitats if they successfully oviposit in the temporary basin.

A number of animals, however, cannot complete their life cycles in temporary water. These animals (e.g., Amphibia, Hemiptera, some Coleoptera, some other insects) may be present in the temporary system when water occupies the basin, but they must migrate to permanent water when such systems dry up.

Moore (1970) recognizes three basic types of seasonal succession within temporary habitats, and Figure 32 is a schematic summary of these succession types using Sounding Creek inhabitants as examples.

Intrinsic (obligate) inhabitants are true temporary water animals such as anostracans and conchostracans (Figure 32A, B). *Lynceus*

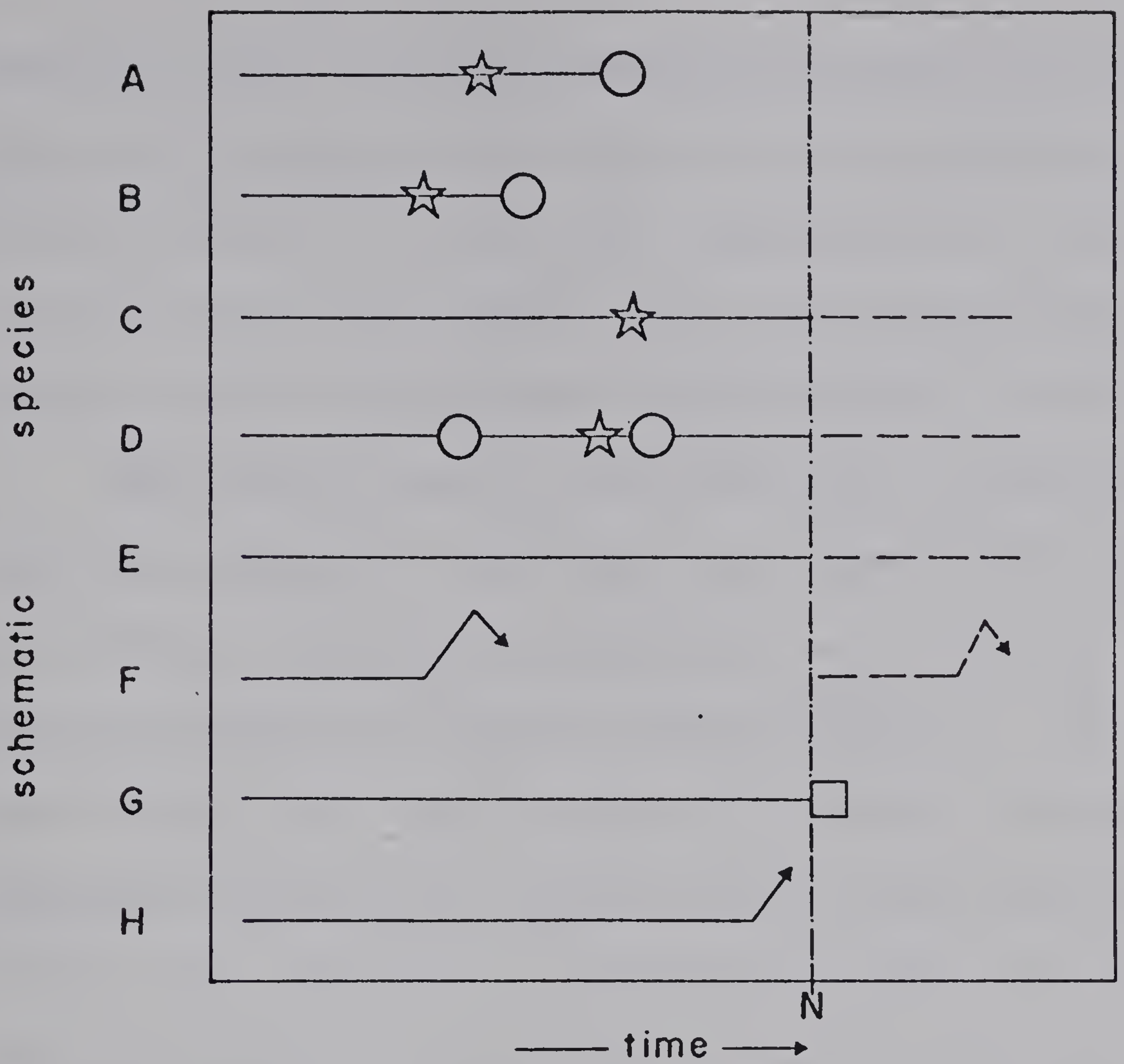

Figure 32. Schematic representation of animal types in temporary habitats (N indicates the habitat has dried up.)

— — — facultative life extension

○ normal termination of life cycle

animal has emerged, but can lay eggs in temporary systems

□ death of permanent water, non-facultative type

animal has emerged from the temporary system but must lay eggs in permanent water

☆ production of resting eggs

(See text for further details)

brachyurus and *L. mucronatus* are typical temporary water animals. *L. mucronatus* is possibly better adapted than *L. brachyurus* to temporary systems because of the more rapid completion of its life cycle. *Cyzicus mexicanus* (Figure 32C) produces eggs prior to desiccation, but requires the same stimuli for successful egg development as other branchiopods.

Many aquatic animals inhabiting astatic habitats fall within the facultative category. Cladocera, e.g., *Daphnia pulex* (Figure 32D), are multivoltine, reproducing asexually for most of the year but occasionally producing desiccation-resistant stages (ephippia). Snails, e.g., *Lymnaea elodes* (Figure 32E), have the ability to secrete a desiccation-resistant ephphragm enabling them to survive for as long as there is moisture present. Many insects, e.g., *Aedes* (Figure 32F), have short life cycles, which nicely adapts them for life in temporary habitats. *Aedes* develop rapidly in early stage ponds, emerge and oviposit in both permanent and temporary systems. A second generation may occur if the aquatic medium persists. However, early hatching has its disadvantages. In the spring of 1973, *Aedes* larvae were abundant at station F on 5 April. On the night of 7 April, the temperature dropped considerably and a 1.5 cm film of ice formed on the water's surface. On 8 April few *Aedes*, which require access to free oxygen, were found.

Permanent water inhabitants follow life cycle patterns similar to those of permanent water; they have not evolved specialized mechanisms for life in temporary habitats. Fish, e.g., *Pimephales promelas* (Figure 32G), although common in temporary basins, must return to free water to overwinter. Spring recolonization is probably through flood overflow and upstream migration from open-water areas. Some insects, e.g., some Coleoptera (Figure 32H), can exist in temporary water but must move out

of the system to complete their life cycle.

Mechanisms of Adaptation

Desiccation-resistant stages. Various aspects of resistant egg stages have been studied by several authors (Broch, 1963; Chodorowski, 1969; Hempel-Zawitkowska, 1971; etc.), but these studies will only be discussed briefly here. As determined by Broch (1963), eggs of *Eubranchipus bundyi* undergo a two-stage development: (1) Prehatched embryos are the overwintering stage (prehatching is triggered by low temperatures and exposure to air). (2) Hatching of the metanauplius is evidently triggered by low oxygen tensions. These conditions are present at the time of inundation and enable the animals to hatch synchronously when the pond fills.

Non-egg stages also are capable of withstanding dry periods. Fourth- and fifth-stage cyclopoid copepodids have been found aestivating in bottom muds to a depth of 5 cm (Wierzbicka, 1972). This author mentions other studies where copepodids in non-static reservoirs could penetrate into the substrate as far as 30 cm. The ability of copepodids to arouse from aestivation in as little as a few minutes (*Cyclops strenuus*) adapts them to life in ephemeral habitats. Wierzbicka also found that copepodids are capable of moving about in the sediment, some remaining active until the desiccatory processes set in. Kenk (1949) noticed the same phenomenon, but determined that complete copepodid desiccation was lethal.

Oxygen. Coincidental with the ability to survive in temporary habitats is the ability to withstand low oxygen concentrations. Moore

and Burn (1968), working on Louisiana temporary ponds, found the daily range of dissolved oxygen was never greater than 0.5 ppm, the actual value being somewhat similar to those of the Sounding Creek area. Daborn (1969) found daily summer oxygen fluctuation in a shallow, central Alberta pond to range no greater than 20 to 30% except when values greatly increased as a result of algal blooms.

Laboratory analysis by Moore and Burn (1968) showed 2-hour LD 50 (concentrations yielding 50% mortality) to be about 0.1-0.4 ppm depending on temperature and the animal tested (mostly crustaceans). Their field observations, however, indicated that oxygen was rarely limiting except to the poor swimming groups, such as Conchostraca. Air-breathing animals and chironomids (much the same community composition as found in Sounding Creek in late summer and mid-October) were not affected at all. Gill breathers, such as fairy shrimp, tended to react to low oxygen tensions by swimming near the surface. However, in more northerly climates, e.g., the Sounding Creek area, fairy shrimp and most other gill-breathing animals are not present in an active life cycle stage when very low oxygen levels occur. A one-week total lack of subsurface oxygen appeared to have no effect on any of the temporary water inhabitants except the Conchostraca (Moore and Burn, 1968).

Brungs (1971), working with *Pimephales promelas*, the fathead minnow, found that low oxygen levels affected the fish in a number of ways: (1) the number of eggs produced by females was reduced below oxygen concentrations of 2.0 mg/l; (2) no spawning occurred below 1.0 mg/l; (3) fry growth was reduced below 7.9 mg/l; (4) fry survival was reduced below 4.0 mg/l; (5) 18% of the fry survivors at 4.0 mg/l were deformed.

In short, therefore, animals normally inhabiting temporary ponds are faced with the possible lack of oxygen and these animals possess morphological, phenological and ethological features that allow them to cope with the hostile conditions.

Predation. Another major characteristic of temporary water, thought to be a necessity especially for phyllopod success, is an absence of predators for part or all of the life cycle. Ardo (1948), among others, thought that temporary water animals (particularly phyllopods) avoided competition by utilizing water unfavorable for competing species. The two areas of phyllopod concentration in Sounding Creek (stations 5 and F) have predator populations present (mainly *Rhantus* and *Laccophilus* larvae) when the phyllopods are growing. A few large *Enallagma boreale* and some small *Pimephales promelas* were found near the end of phyllopod succession in 1973. Analysis of *Pimephales* stomachs indicated that they did not feed on fairy shrimp. McCarraher (1959) found that small pike, *Esox lucius* (6.2-8.7 cm), fed heavily on recently hatched fairy shrimp. The lake in question maintained a seasonal run of pike as well as a large population of the fairy shrimp *Eubranchipus bundyi*. McCarraher (1970) also found large numbers of *P. promelas* and the fairy shrimp *Branchinecta lindahli* occurring at the same time in a small alkaline lake.

Although, I feel, predation plays at least a minor role in limiting phyllopod populations, production of large numbers of eggs and the ability to thrive in an otherwise limiting system is the key to this group's success. As Hartland-Rowe (1972) suggests, anostracans are not helpless animals and are quite able to compete successfully even with larger predatory animals.

Effect of floods. Periods of seemingly obvious catastrophic disturbances in Sounding Creek occurred during floods. The most obvious examples of this occurred about 27 July 1972 and 20 June 1973. Except for stations 5 and F (and to a lesser extent station 6), flood waters from upstream areas diluted stream waters considerably (Tables 14 and 15). While the increased water diluted most chemical constituents in the mainstream stations, chemical concentrations at station F were maintained or increased and station 5 exhibited a dampened effect, even though both areas were extensively flooded. Therefore, I suggest that surface runoff received at station F is of much higher chemical content than that affecting the other stations. The flood water directly affecting station F originated in a large borrow pit 100 m west of the study area and flowed over large areas of crystallized salt deposits.

The floods (particularly the 1973 flood) had catastrophic effects on the stream's fauna (refer to Results section for discussion of the floods' effect on individual groups). Although some groups (e.g., Trichoptera Table 29) increased in numbers as a result of the flood, most groups decreased in numbers. Figures 33 and 34 show the general effect of the 1973 flood on the biological community. Planktonic animals are much more susceptible to flow than the benthos and consequently there was a reduction in pelagic animals (expressed as a greater percentage of benthos). It appears that effects of floods are rather short-lived and populations tended to rapidly return to normal.

Floods may also play a major role in dispersion of temporary water inhabitants. As mentioned by Hartland-Rowe (1972), some outside means of dispersal is required for temporary water animals because

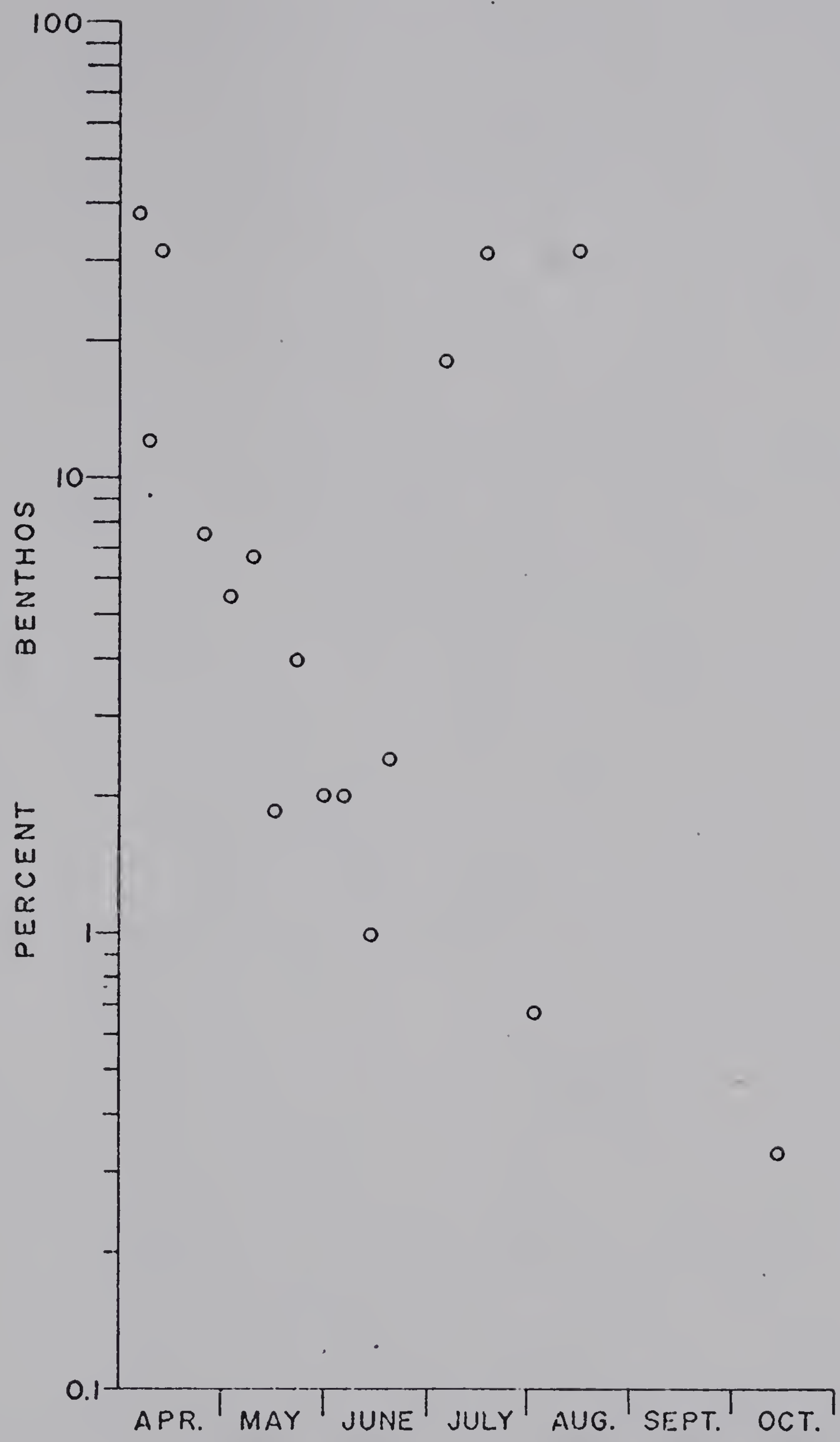

Figure 33. Bentho-Pelagic index (expressed as percent benthos) from Sounding Creek station 6, 1973 (see text for further details)

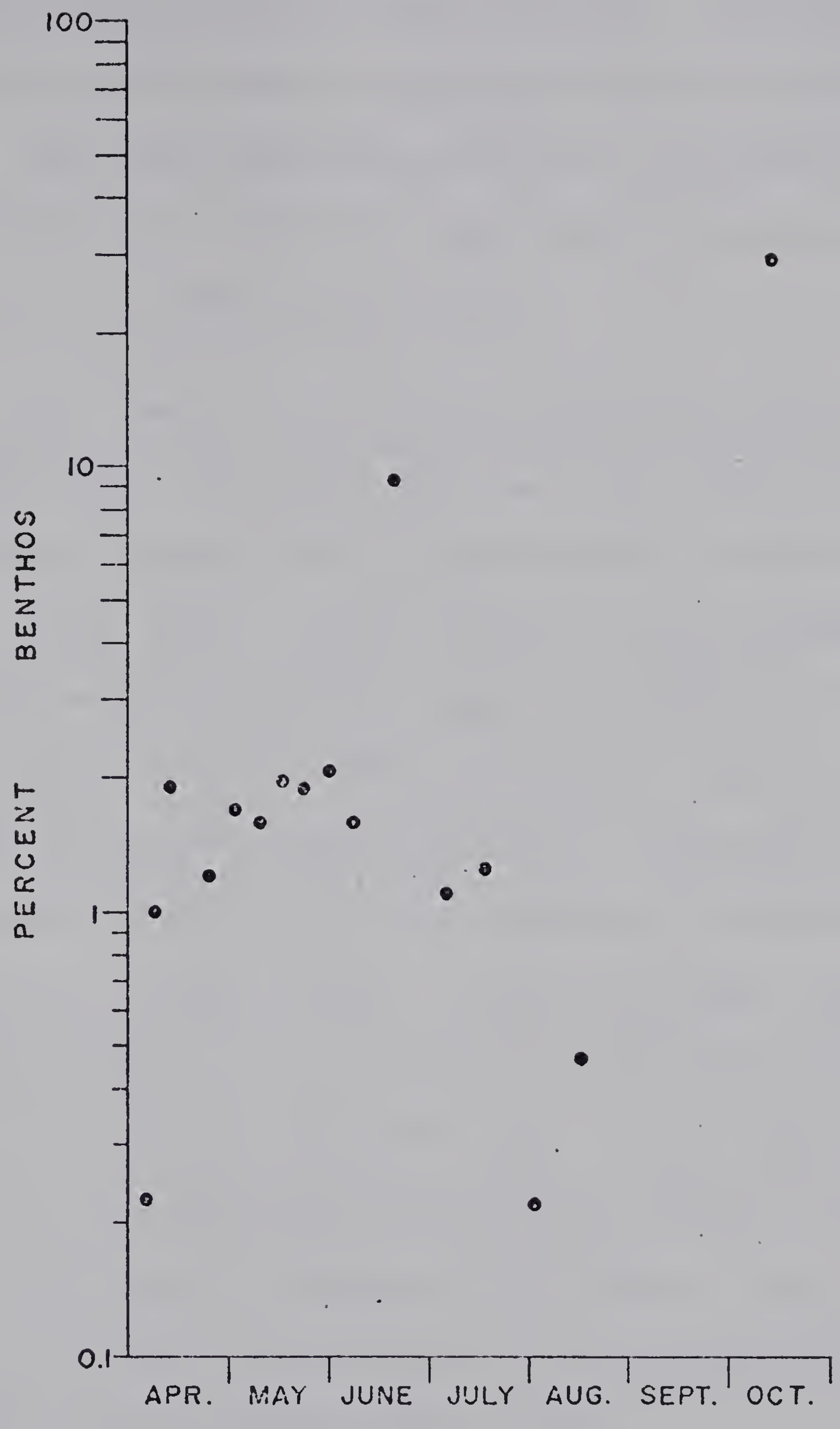

Figure 34. Bentho-Pelagic index (expressed as percent benthos) from Sounding Creek station F, 1973 (see text for further details)

astatic waters are usually located in isolated basins. The heavy rains of June 1973 caused Sounding Creek to completely breach its banks by at least 0.5 meter. This would seem to be sufficient to disperse resting eggs and, because there was still water present in the basin at the time of flooding, immature and adult stages as well.

Heterogeneity. There is little habitat diversity during early seasonal succession stages (at least partly due to the lack of aquatic plants), and temporary habitats tend to have relatively restricted faunas in spring (Moore, 1970). However, because of the abundance of microorganisms flourishing during early stages (presumably due to the large amounts of organic material present at breakup), early succession stages are dominated by filter feeders (Anostraca, Conchostraca, etc.). As observed in Sounding Creek, these animals generally declined in numbers over a period of several weeks. As the water warms, aquatic plants start to grow and an increase in habitat heterogeneity occurs, resulting in the appearance of many animal types. As the season progresses and the water evaporates, the shallower areas are invaded by semi-aquatic reeds and later by semi-terrestrial sedges. Then, as moisture evaporates from the exposed bottom, the area becomes more suitable for grasses and terrestrial faunas appear.

In Sounding Creek the group of secondary inhabitants (those appearing in conjunction with plant proliferation) are dominated by herbivores (e.g., *Limnephilus*, *Agrypnia*) and predatory insects (e.g., *Lestes* spp. and a variety of Coleoptera). In late summer and early fall, as temperatures and water levels decline, plant heterogeneity decreases and the most abundant animals are mobile, pelagic air breathers (e.g.,

Coleoptera and Hemiptera.

The "*bentho-pelagic*" index, a ratio of benthic animals (animals spending most of their time in close association with the bottom, e.g., chironomids, snails, etc.) to pelagic animals (animals spending a good deal of their time free swimming, e.g., anostracans, conchostracans, etc.), gives an indication of the community response to changes in heterogeneity and flood. Figure 34 shows changes occurring in the ratio at station F. When free water first enters the basin in spring, the community consists of predominantly planktonic animals. As emergent and submergent macrophytes appear, benthic forms rapidly become evident and the ratio shifts towards a greater abundance of benthic types. Further in the season, however, when the basin dries and benthic insects emerge, the ratio shifts again towards the pelagic types (e.g., Hemiptera, Copeoptera).

The permanent and semi-permanent stations, station 1 (Figure 35) and station 6 (Figure 33), are characterized by unidirectional flow in the spring. As a result, there are few planktonic animals and the bentho-pelagic ratio approaches total benthos (100%). However, as stream flow decreases, pelagic animals invade these stations. Generally, therefore, factors controlling populations at all stations seem to be related to changes in habitat heterogeneity.

CHANGE IN SALINITY

The Sounding Creek basin has little precipitation during the summer months and salinity gradually increases as water levels fall. In Sounding Creek, salinity possibly limits the occurrence of animals only

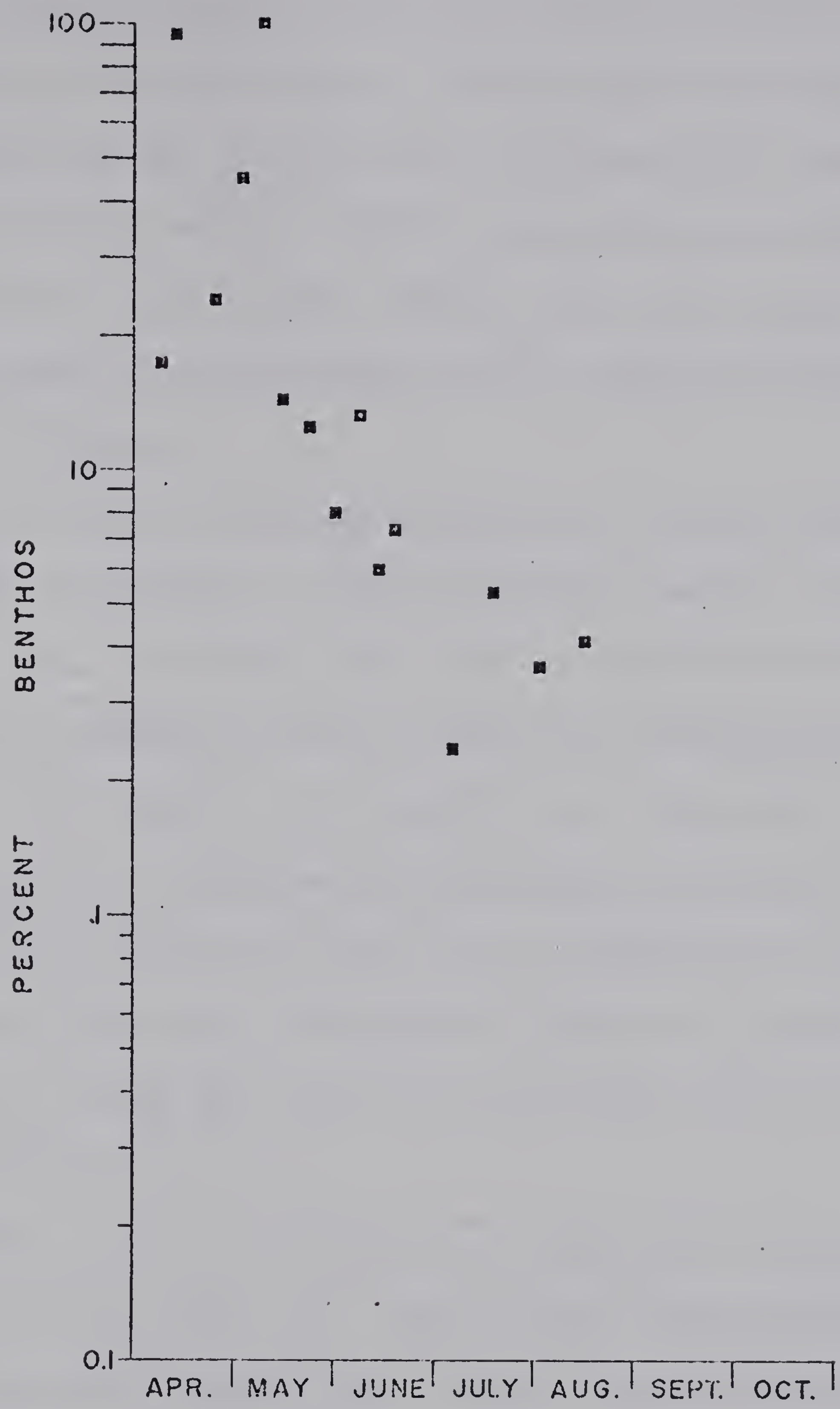

Figure 35. Bentho-Pelagic index (expressed as percent benthos) from Sounding Creek station 1, 1973 (see text for further details)

in mid and late summer and again in winter, at which time chemical constituents are concentrated by ice. In both years of my study, however, heavy and periodic rains in late spring and early summer had a diluting effect and high salinity did not occur until much later in the year (late August and early autumn). For the most part, animals inhabiting the stream at this time were mobile, transient organisms such as Hemiptera and Coleoptera.

Survival in temporary habitats having very high salinities depends on almost complete independence of the body fluids from the external medium. Beadle (1943) identified three types of organisms in temporary saline waters: (1) organisms normally inhabiting freshwater with less than 20,000 mg/l T.D.S. (most of the Sounding Creek fauna falls within this classification); (2) organisms prefering saline water (up to 50,000 mg/l T.D.S.) but which can also occur in freshwater (e.g., *Cyclops bicuspidatus*, *Cyprinodon* spp.); (3) organisms confined to highly saline water (greater than 50,000 mg/l T.D.S. to near saturation), e.g., *Artemia*, *Aedes detritus*, *Ephydra* sp.

Most animals present in Sounding Creek, which has a salinity range of 588 mg/l to 2077 mg/l T.D.S. (about 1000 to 3500 micromhos conductivity), are typical inhabitants of western Canadian areas of low or moderate salinity and would therefore be in the above freshwater category (1) (Rawson and Moore, 1944; Kenk, 1949; Hartland-Rowe, 1966; Scudder, 1969; etc.). However, many species found in Sounding Creek (mostly mobile forms such as hemipterans and coleopterans) are capable of inhabiting water of relatively high salinity (up to 30,000 micromhos conductivity--about 18,000 mg/l T.D.S.).

With a few exceptions (e.g., *Artemia*), freshwater (athalassic) animals are unable to maintain hypotonic blood (Beadle, 1959). Through low permeability of the body surface and an excretory mechanism that concentrates urine, aquatic insects, entomostracans and rotifers that tolerate high salinities maintain body fluids hypotonic to the external medium. For most freshwater animals, however, the salinity tolerance limit is usually reached when the internal body fluids are isotonic to the external medium (this is up to about 15,000 mg/l of total salts). Above 50,000 mg/l, a strong mechanism to maintain hypotonic body fluids is required.

Because branchiopods and other entomostracans are typical of temporary waters, most examples of salinity tolerance pertain to them. Hartland-Rowe (1966) identified three salinity groupings of Anostraca: (1) species that are confined to low salinity (e.g., *Eubranchipus* spp. and *Streptocephalus* spp.), (2) species confined to high salinities (e.g., *Artemia*), and (3) species that occur in a range of salinities (e.g., *Branchinecta*). Some phyllopods, formerly thought to be typical of both saline and temporary habitats, are now known not to be able to survive in hypertonic media (Panikkar, 1941), and these organisms are confined to lower salinities (less than 1000 mg/l T.D.S.). Most Anostraca, however (including most of those found in Sounding Creek), are recorded from lakes and small water bodies with wide-ranging salinities and these animals have evolved mechanisms to endure considerable change in salinity.

Beadle (1943) determined that an important limiting factor for animals inhabiting saline water bodies was total salinity, not diversity of ions. Eriksen (in Hartland-Rowe 1966), however, suggested that,

particularly in the case of *Branchinecta mackini*, absolute ion concentration was not the limiting factor; but, instead, the relative concentrations of the different ions was the limiting factor. Working with *Triops* (Notostraca), which is sensitive to magnesium and thus excluded from waters having high magnesium contents, Horne (1966) also suggested that ionic composition was more important than total concentration.

CONCLUSION

Temporary waters are quite common in Alberta, especially temporary, saline waters in the eastern part of the province. The ultimate control of the overall environment of temporary habitats is usually dependent on large-scale influences (e.g., precipitation).

Inland drainage basins, such as the Sounding Creek Basin in Alberta, are of considerable biological interest, and from my account of an astatic environment, it is evident that within even the narrow bounds of the study area, there exists extensive seasonal environmental fluctuations. Because of the transient nature of temporary habitats, colonizing organisms must be able to react rapidly to the wet phase and reach maturity in as little time as possible. Although osmotic relationships are important for survival, temperature, oxygen concentration, food availability, and the ability to withstand desiccation set the limits of a particular species range and determine overall successional patterns.

LITERATURE CITED

Ahlstrom, E. H. 1940. A revision of the rotatorian genera *Brachionus* and *Platyias* with descriptions of one new species and two new varieties. Bull. Am. Mus. nat. Hist. 77:143-184.

Ahlstrom, E. H. 1943. A revision of the rotatorian genus *Keratella* with descriptions of three new species and five new varieties. Bull. Am. Mus. nat. Hist. 80:411-457.

American Public Health Association. 1971. Standard Methods for the Examination of Water and Wastewater (13th ed.). Washington, D.C. 874 p.

Ardo, P. 1948. Some notes on the phyllopods in temporary pools on the Alvar of Oland in south Sweden. Lunds Univ. Arsskr. 44:1-22.

Beadle, L. C. 1943. Osmotic regulation and the faunas of inland waters. Biol. Rev. 18:172-183.

Beadle, L. C. 1959. Osmotic and ionic regulation in relation to classification of brackish and inland saline waters. Arch. Oceanogr. e Limnol. 11, Suppl.:143-151.

Beadle, L. C. 1969. Osmotic regulation and the adaptation of freshwater animals to inland saline waters. Symposium on salt and brackish inland waters. Verh. Internat. Verein. Limnol. 17:421-429.

Brandlova, J., Z. Brandl and C. H. Fernando. 1972. The Cladocera of Ontario with remarks on some species and distribution. Can. J. Zool. 50:1373-1403.

Broch, E. S. 1963. Ecology and physiology of the embryonated egg of the fairy shrimp *Chirocephalopsis bundyi* Forbes, with reference to factors synchronizing the life cycle to the temporary pond. Ph.D. Thesis, Cornell University, Dept. of Zoology. 168 p.

Broch, E. S. 1965. Mechanism of adaptation of the fairy shrimp *Chirocephalopsis bundyi* Forbes, to the temporary pond. Cornell Univ. Agric. Exp. Stn. Mem. No. 392.

Brooks, A. R. and L. A. Kelton. 1967. Aquatic and semi-aquatic Heteroptera of Alberta, Saskatchewan and Manitoba (Hemiptera). Mem. Ent. Soc. Canada No. 51.

Brooks, J. L. 1957. The systematics of North American *Daphnia*. Mem. Conn. Acad. Arts Sci. 13, 180 p.

Brungs, W. A. 1971. Chronic effects of low dissolved oxygen concentrations on the fathead minnow (*Pimephales promelas*). J. Fish. Res. Bd. Canada 28:1119-1123.

Chodorowski, A. 1969. The desiccation of ephemeral pools and the rate of development of *Aedes communis* larvae. Pol. Arch. Hydrobiol. 16: 79-91.

Cole, G. A. 1967. Contrasts among calanoid copepods from permanent and temporary ponds in Arizona. Am. Midl. Nat. 76:351-368.

Daborn, G. R. 1969. Transient ecological succession in a shallow pond. M.Sc. Thesis, Univ. of Alberta, Dept. of Zoology, 104 p.

Daborn, G. R. 1974. Biological features of an aestival pond in western Canada. Hydrobiologia 44:287-299.

Daborn, G. R. 1974. Length-weight allometric relationships in four crustaceans from Alberta lakes and ponds. Can. J. Zool. 52: 1303-1310.

Daborn, G. R. and H. F. Clifford. 1974. Physical and chemical features of an aestival pond in western Canada. Hydrobiologia 44:43-59.

Edmondson, W. T. 1959. Fresh-water biology. John Wiley and Sons, Inc., New York. 1248 p.

Goulden, C. E. 1968. The systematics and evolution of the Moinidae. Trans. Am. phil. Soc. 58, 101 p.

Green, J. and O. B. Lan. 1973. *Asplanchna* and the spines of *Branchionus calyciflorus* in two Javanese sewage ponds. Freshwat. Biol. 4: 223-226.

Gurney, R. 1925. The nauplius of *Limnetis gouldi*. Internat. Rev. Hydrobiol., Leipzig 16:114-117.

Hartland-Rowe, R. 1966. The fauna and ecology of temporary pools in western Canada. Verh. Internat. Verein. Limnol. 16:577-584.

Hartland-Rowe, R. 1967. *Eubranchipus intricatus* n. sp., a widely distributed North American fairy shrimp, with a note on its ecology. Can. J. Zool. 45:663-666.

Hartland-Rowe, R. 1972. Aspects of the limnology of temporary waters and the ecology of the Euphyllopoda. Essays in Hydrobiology, Exeter University:15-31.

Hempel-Zawitkowska, J. 1971. Resistance of eggs of *Triops cancriformis* to low temperatures as related to several chosen environmental factors. Pol. Arch. Hydrobiol. 18:295-302.

Holmgren, E. J. and P. M. Holmgren. 1972. 2000 place names of Alberta. Modern Press, Saskatoon. 226 p.

Horkan, J. P. K. 1971. Some ecological effects of thermal pollution on Lake Wabamun, Alberta, with special reference to the Rotifera. M.Sc. Thesis, Univ. of Alberta, Dept. of Zoology. 168 p.

Horne, F. 1966. Some aspects of ionic regulation in the freshwater crustacean, *Triops longicaudus*. Comp. Biochem. Physiol. 19:313-316.

Hotchkiss, N. 1972. Common marsh, underwater and floating-leaved plants of the United States and Canada. Dover Publications, Inc., New York. 124 p.

Hutchinson, G. E. 1937. A contribution to the limnology of arid regions. Trans. Conn. Acad. Arts Sci. 33:47-132.

Jewell, M. E. 1927. The aquatic biology of the prairie. Ecology 8: 289-298.

Johansen, F. 1921. The larger freshwater Crustacea from Canada and Alaska. Can. Fld. Nat. 35:88-94.

Kenk, R. 1949. The animal life of temporary and permanent ponds in southern Michigan. Misc. Publs. Mus. Zool., Univ. of Michigan, No. 71.

Klimowicz, H. 1967. Rotifers of astatic waters. Part II. Rotifers of small water bodies from the Mikolajki region. Pol. Arch. Hydrobiol. 14:91-110.

Lippert, B. E. and D. L. Jameson. 1964. Plant succession in temporary ponds ofthe Willamette Valley, Oregon. Am. Midl. Nat. 71:181-197.

Loewengart, S. 1961. Airborn salts--the major source of the salinity of waters of Israel. Bull. Res. Coun. Israel 10:183-206.

Longley, R. W. 1972. The climate of the prairie. Environment Canada--Atmospheric Environment, Climatological Studies, No. 13.

Mahlis, A. M., S. A. Morcos and S. K. El-Wakeel. 1970. The major anions in Lake Maryut waters. Hydrobiologia 36:275-294.

McCarraher, D. B. 1959. Phyllopod shrimp populations of the Big Alkali Lake drainage, Nebraska and their relationships to young pike (*E. lucius*). Am. Midl. Nat. 61:509-510.

McCarraher, D. B. 1970. Some ecological relations of fairy shrimps in alkaline habitats in Nebraska. Am. Midl. Nat. 84:59-68.

McCarraher, D. B. 1972. A preliminary bibliography and lake index of the inland mineral waters of the world. FAO Fisheries Circular, No. 146.

McMillan, V. 1973. Breeding behavior of the fathead minnow. Blue Jay 31:142-146.

Moore, J. E. 1952. The Entomostraca of southern Saskatchewan. Can. J. Zool. 30:410-450.

Moore, W. G. 1951. Observations on the biology of *Streptocephalus seali*. Proc. Louisiana Acad. Sci. 14:57-65.

Moore, W. G. 1970. Limnological studies on temporary ponds in south-eastern Louisiana. SWest. Nat. 15:83-110.

Moore, W. G. and A. Burn. 1968. Lethal oxygen thresholds for certain temporary pond invertebrates and their applicability to field situations. Ecology 49:349-352.

Mozley, A. 1932. A biological study of a temporary pond in western Canada. Am. Nat. 66:236-249.

Mozley, A. 1938. The Quill Lakes Basin, Saskatchewan, Canada and its mossuscan fauna. Int. Rev. Ges. Hydrobiol. Hydrogr. 38:243-249.

Needham, J. G. and M. J. Westfall. 1955. Dragonflies of North America. Univ. of California Press, Berkeley. 615 p.

Neill, C. R., D. I. Bray, M. F. Schouten and J. R. Card. 1970. Selected characteristics of streamflow in Alberta. Research Council of Alberta and Alberta Dept. of Agriculture, River Engineering and Surface Hydrology Report No. 7071. 55 p.

Packard, A. S. 1875. New Phyllopod crustaceans. Am. Nat. 9:311-312.

Panikkar, N. K. 1941. Osmotic behavior of the fairy shrimp, *Chirocephalus diaphanus* Prevost. J. Exp. Biol. 18:110-114.

Pennak, R. W. 1953. Freshwater invertebrates of the United States. Ronald Press Co., New York. 796 p.

Pilarska, J. 1972. The dynamics of growth of experimental populations of the rotifer *Branchionus rubens*. Pol. Arch. Hydrobiol. 19:265-277.

Pinsent, M. E. 1967. A comparative limnological study of Lac la Biche and Beaver Lake, Alberta. M.Sc. Thesis, Dept. of Zoology, Univ. of Alberta, Edmonton. 147 p.

Pionke, H. B. and A. D. Nicks. 1970. The effect of selected hydrologic variables on stream salinity. Bull. Int. Assoc. Scientific Hydrology 15:13-21.

Pionke, H. B. and D. D. Workman. 1972. Salinity problems of impoundments and their management. *In* Great Plains Agricultural Council, No. 60:155-167.

Pionke, H. B., A. D. Nicks and R. R. Schoof. 1972. Estimating salinity of streams in the southwestern United States. Wat. Resour. Res. 8:1597-1604.

Prescott, G. W. 1970. How to know the freshwater algae. W. G. Brown Co. Dubuque, Iowa. 348 p.

Rawson, D. S. and J. E. Moore. 1944. The saline lakes of Saskatchewan. Can. J. Res. 22:141-201.

Remane, A. and C. Schlieper. 1971. Biology of brackish water. Binnengewasser 25: 372 p.

Rowe, J. S. 1972. Forest regions of Canada. Canadian Forest Service, No. 1300.

Sawchyn, W. W. and U. T. Hammer. 1968. Growth and reproduction of some *Diaptomus* spp. in Saskatchewan ponds. Can. J. Zool. 46:511-520.

Scudder, G. G. E. 1969. The fauna of saline lakes on the Fraser Plateau in British Columbia. Verh. Internat. Verein. Limnol. 17: 430-439.

Smith, G. M. 1950. The freshwater algae of the United States. McGraw-Hill Book Co. Ltd., New York. 719 p.

Solowiow. 1927. Zur biologie von *Limnetis brachyura*. Zool. Anz. 74: 151-157.

Tribbey, B. A. 1965. A field and laboratory study of ecological succession in temporary ponds. Ph.D. Thesis, Univ. of Texas, Dept. of Zoology. 233 p.

Usinger, R. L. 1956. Aquatic insects of California. Univ. of California Press, Berkeley, California. 508 p.

Walker, E. M. 1953. The Odonata of Canada and Alaska. Volume I. University of Toronto Press, Toronto, Ontario. 292 p.

Wierzbicka, M. 1972. Distribution of Cyclopoida copepodites in the resting stage in bottom sediments of astatic reservoirs. Pol. Arch. Hydrobiol. 19:369-376.

Wiggins, G. B. 1973. A contribution to the biology of caddisflies (Trichoptera) in temporary pools. Life Sci. Contr. R. Ont. Mus. No. 88.

Wiktor, K. 1968. Seasonal modification in fertility of some Rotifera species. Pol. Arch. Hydrobiol. 15:9-22.

Wyatt, F. A., J. D. Newton, W. E. Bowser and W. Odynsky. 1938. Soil survey of Sullivan Lake sheet. University of Alberta, College of Agriculture. No. 31.

APPENDICES

APPENDIX I

PROVISIONAL TAXON LIST

SOUNDING CREEK, ALBERTA

Chlorophyta

Ankistrodesmus sp.

Cosmarium sp.

Pediastrum sp.

Scenedesmus sp.

Spirogyra sp.

Staurastrum sp.

Stigeoclonium sp.

Euglenaphyta

Phacus sp.

Chrysophyta

Asterionella sp.

Diatoma sp.

Fragillaria sp.

Gomphonema gracile Ehrenberg

Gomphonema sp.

Gyrosigma sp.

Nitzchia palea (Kutz.)

Nodularia sp.

Synedra acus Kutz.

Synedra puchella Kutz.

Pyrrophyta

Ceratium hirundinella (O.F.M.)

Gymnodinium sp.

Cyanophyta

Anabaena sp.

Aphanizomenon fos-aquae (L.)

Gleotrichia sp.

Nostoc sp.

Oscillatoria sp.

Metaphytes (higher aquatic plants)

Carex sp.

Eleocharis palustris (L.)

Elodea canadensis Mitchx.

Lemna minor L.

Lemna trisulca L.

Sagittaria latifolia (Willd.)

Scirpus validus Vahl.

Sium suave Walt.

Coelenterata

Hydra sp.

Rotifera

Asplanchna sp.

Brachionus angularis (Gosse)

Brachionus bidentata (Andersen)

Brachionus calyciflorus Pallas

Brachionus caudatus (Barrois)

Brachionus quadridentata (Hermann)

Brachionus plicatilis (complex)

Colurella sp.

Conochilus unicornis Rousselet

Euchlanis sp.

Filinia longiseta Ehrenberg

Kellicotia longispina (Kellicott)

Keratella cochlearis (Gosse)

Keratella quadrata (Muller)

Lecane sp.

Lepadella sp.

Monostyla sp.

Mytilina sp.

Notholca acuminata (Ehrenberg)

Platyias quadricornis (Ehrenberg)

Polyarthra vulgaris Carlin

Pomopholyx sp.

Rotaria sp.

Sinantherina sp.

Synchaeta sp.

Testudinella patina (Hermann)

Trichotria sp.

Bryozoa

Fredericella sultana (Blumenbach)

Plumatella repens (L.)

Tardigrada

One specimen found

Annelida

Hirudinea

Erpobdella punctata (Leidy)

Glossiphonia complanata (L.)

Oculobdella lucida Meyer and Moore

Theromyzon rude (Baird)

Oligochaeta

Aeolosoma sp.

Chaetogaster sp.

Nais sp.

Arthropoda

Crustacea

Anostraca

Branchinecta mackini Dexter

Branchinecta paludosa (O.F.M.)

Eubranchipus bundyi (Forbes)

Eubranchipus intricatus Hartland-Rowe

Eubranchipus ornatus Holmes

Streptocephalus seali Ryder

Conchostraca

Cyzicus mexicanus (Claus)

Lynceus brachyurus O.F.M.

Lynceus mucronatus (Packard)

Notostraca

Lepidurus couesii Packard

Cladocera

Alona costata Sars

Alona guttata Sars

Alona rectangula Sars

Alonella excisa (Fischer)

Bosmina longirostris (O.F.M.)

Ceriodaphnia affinis Lilljeborg

Chydorus sphaericus (O.F.M.)

Daphnia magna Straus

Daphnia middendorfiana Fischer

Daphnia parvula Fordyce

Daphnia pulex Leydig

Daphnia rosea Sars

Diaphanosoma brachyurum (Lieven)

Dunhevedia crassa King

Ilyocryptus sordidus (Lieven)

Kurzia latissima (Kurz)

Leydigia leydigii (Schoedler)

Macrothrix laticornis (Jurine)

Macrothrix rosea (Jurine)

Moina affinis Birge

Moina macrocopa Straus

Moina weirsejskii (Richard)

Pleüroxus aduncus (Jurine)

Scapholeberis kingi Sars

Simocephalus serrulatus (Koch)

Simocephalus vetulus Schodler

Ostracoda

Candona acutula Delorme

Candona rawsoni Tressler

Candona sp.

Cyclocypris sharpei Furtos

Cypricercus horridus Sars

Cypridopsis vidua (Muller)

Cypris pubera Muller

Limnocythere sp.

Copepoda

Calanoida

Diaptomus clavipes Schacht

Diaptomus clavipoides M. S. Wilson

Diaptomus eiseni Lilljeborg

Diaptomus forbesi Light

Diaptomus leptopus S. A. Forbes

Diaptomus nevadensis Light

Diaptomus nudus Marsh

Diaptomus sanguineus S. A. Forbes

Diaptomus sicilis S. A. Forbes

Diaptomus siciloides Lilljeborg

Copepoda

Cyclopoida

Cyclops vernalis Fischer

Eucyclops speratus (Lilljeborg)

Macrocyclops albidus (Jurine)

Amphipoda

Gammarus lacustris Sars

Hyalella azteca (Saussure)

Arthropoda

Insecta

Ephemeroptera

Caenis sp.

Callibaetis pallidus Banks

Centroptilum sp.

Paraleptophlebia praepedita (Eaton)

Odonata

Enallagma boreale Selys

Lestes congener Hagen

Lestes disjunctus Selys

Lestes dryas Kirby

Lestes unguiculatus Hagen

Tarnetrum corruptum Hagen

Hemiptera

Callicorixa audeni Hungerford

Cenocorixa bifida (Hungerford)

Cenocorixa dakotensis (Hungerford)

Corisella tarsalis (Fieber)

Cymatia americana Hussey

Gerris buenoi Kirkaldy

Hesperocorixa atopodonta (Hungerford)

Hesperocorixa laevigata (Uhler)

Hesperocorixa vulgaris (Hungerford)

Lethocerus americanus (Leidy)

Notonecta kirki Hungerford

Notonecta undulata Say

Sigara alternata (Say)

Sigara bicoloripennis (Walley)

Sigara solensis (Hungerford)

Saldula pallipes (Fabricius)

Trichocorixa borealis Sailer

Trichocorixa verticalis interiores Sailer

Coleoptera

Acilius semisulcatus Aube

Agabus sp.

Colymbetes sculptilis Harris

Dactylosternum sp.

Dytiscus circumcinctus Ahrens

Enochrus horni Leech

Graphoderus occidentalis Say

Gyrinus maculiventris LeC.

Gyrinus pectoralis LeC.

Haliplus immaculicollis Harris

Helophorus sp.

Hydrobius fuscipes L.

Hydroporus sp.

Hygrotus sp.

Laccophilus biguttatus Kirby

Peltodytes sp.

Rhantus consimilis Motschoulsky

Rhantus frontalis (Marsham)

Tropisternus lateralis limbalis LeC.

Trichoptera

Agrypnia pagatena Curtis

Limnephilus spp.

Oecetis immobilis (Hagen)

Triaenodes sp.

Diptera

Culicidae

Aedes sp.

Anopheles sp.

Chaeborus americana Joh.

Culex sp.

Culiseta sp.

Mochlonyx sp.

Psorophora sp.

Chironomidae

Corynoneura sp.

Crytotendipes sp.

Cricotopus sp.

Glyptotendipes sp.

Hydrobaenus sp.

Psectrotanypus sp.

Ceratopogonidae

Palpomyia sp.

Dixidae

Dixa sp.

Tipulidae

Tipula sp.

Limnophila sp.

Simuliidae

Cnephia sp.

Simulium vittatum Zetterstedt

Stratiomyidae

Stratiomys sp.

Dolichopodidae

Dolichoptus sp.

Mollusca

Gastropoda

Gyraulus deflectus (Say)

Lymnaea elodes (Say)

Lymnaea caperata (Say)

Lymnaea reflexa (Say)

Lymnaea stagnalis (Say)

Physa gyrina (Say)

Promenetus umbilicatellus (Cockerell)

Pelecypoda

Pisidium cf. *ferrugineum* Prime

Chordata

Vertebrata

Amphibia and Reptilia

Ambystoma tigrinum (Green)

Bufo hemiophrys Cope

Rana pipiens Schreber

Rana sylvatica LeConte

Thamnophis radix (Baird and Girard)

Aves (residents or frequent visitors)

Anas acuta L. - pintail

Anas discors L. - blue-winged teal

Anas platyrhynchus L. - mallard

Fulica americana Gmelin - coot

Mareca americana (Gmelin) - baldpate

Porzana carolina (L.) - sora rail

Podiceps auritus Gmelin - horned grebe

Spatula cyypeata (L.) - shoveler

Pisces

Culaea inconstans (Kirtland)

Pimephales promelas Rafinesque

Mammalia

Castor canadensis Kuhl.

Mustela vison Schreber

Ondatra zibethicus (L.)

and

Bos taurus L.

APPENDIX II

Seasonal changes in total hardness (expressed as mg/liter calcium carbonate) in Sounding Creek water, 1972 and 1973

Date	Station 1	2	3	4	6	5	F
04/19/72	160	146	155	148	148	124	-
05/3/72	188	172	212	196	178	188	-
05/25/72	181	193	530	254	184	297	-
06/16/72	238	222	-	312	236	348	-
07/7/72	166	144	-	244	-	160	-
07/27/72	88	72	104	86	100	88	-
08/16/72	168	180	270	242	228	164	-
10/7/72	220	276	296	260	264	280	-
12/28/72	552	-	-	-	-	-	-
04/15/73	132	-	128	136	168	120	116
04/25/73	148	-	148	140	136	120	132
05/2/73	132	-	132	152	148	132	124
05/9/72	160	-	120	180	176	152	132
05/16/73	172	-	176	180	184	172	140
05/22/73	184	-	192	196	200	200	156
05/30/73	196	-	216	208	192	196	164
06/7/73	220	-	248	244	264	184	172
06/13/73	224	-	256	248	260	240	180
06/20/73	116	-	116	124	128	192	200
07/5/73	152	-	148	152	156	168	180
07/17/73	132	-	112	136	136	180	176
08/1/73	148	-	156	172	176	220	220
08/15/73	256	-	172	168	168	164	168
10/13/73	252	-	268	280	288	220	228

APPENDIX III

Seasonal changes in calcium hardness (expressed as mg/liter calcium carbonate) in Sounding Creek water, 1972 and 1973

Date	Station 1	2	3	4	6	5	F
04/19/72	75	77	77	77	78	70	-
05/3/72	86	84	107	94	91	107	-
05/25/72	102	95	211	117	91	158	-
06/16/72	120	115	-	126	119	195	-
07/7/72	60	58	-	122	-	36	-
07/27/72	46	52	52	52	52	48	-
08/16/72	90	104	120	114	106	110	-
10/7/72	132	126	146	142	128	134	-
12/28/72	270	-	-	-	-	-	-
04/15/73	66	-	70	68	66	66	56
04/25/73	74	-	72	76	78	68	54
05/2/73	84	-	86	84	84	72	64
05/9/73	90	-	98	90	86	88	84
05/16/73	102	-	102	100	96	100	82
05/22/73	110	-	108	104	100	106	90
05/30/73	118	-	118	108	114	114	100
06/7/73	122	-	134	126	124	128	100
06/13/73	126	-	132	126	128	136	98
06/20/73	68	-	68	74	66	98	102
07/5/73	78	-	84	76	82	88	98
07/17/73	60	-	64	76	62	100	110
08/1/73	72	-	72	76	70	112	124
08/15/73	120	-	104	102	86	104	102
10/13/73	132	-	120	146	148	110	134

APPENDIX IV

ASSORTED CHEMICAL ANALYSES (FEDERAL DEPARTMENT OF THE ENVIRONMENT - INLAND WATERS)

	July 7 1971	July 20 1971	June 1 1972	May 29 1973	Aug 3 1973	Feb 15 1974
chlorophyll 'a'	-	-	-	-	0.21	0.06
chloride	-	-	-	-	21.0	113.0
Kjeldahl nitrogen	-	-	-	-	5.7	6.9
phosphorus (total)	-	-	-	-	2.8	0.35
potassium	-	-	-	-	16.0	30.0
conductance	-	-	-	-	1170.0	5600.0
alkalinity (total)	-	-	-	-	358.0	1118.0
hardness (total)	-	-	-	-	115.0	852.0
calcium	-	-	-	-	42.0	171.0
sulphate	-	-	-	-	290.0	2180.0
sodium	-	-	-	-	240.0	1210.0
aluminum	8.6	9.1	3.5	0.14	7.3	0.46
iron	5.6	5.2	3.0	0.58	14.1	2.0
manganese	0.12	0.29	0.34	0.35	0.52	2.5